The London School of Economics and Political Science

Economics Essays on Rice Seed Security and Sovereignty in Guinea Bissau

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Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

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Abstract

This thesis aims to examine the status of seed security and seed sovereignty among female lowland rice farmers in Guinea Bissau. It draws from different, while complementary strands of the literature, investigating seed systems. One focusing on functional aspects of farmers' seed systems, such as availability, access and varietal suitability, while the other stems from seed sovereignty movement which looks at seed systems from a rights perspective. This research objective is to contribute to this literature by providing new insights on seed security measures, quantitative evidence of the effects of seed security on food production and on how farmers, in context of limited statehood can protect their rights under a multi-level governance system "pushing" their rights' in different directions. Chapter 1 provides an introduction on the issues surrounding seed systems, seed security and seed sovereignty in developing countries, the motivation and the research objectives. Chapter 2 develops a comprehensive measure of seed security with the objective to capture in a single measure all the different dimensions behind seed security. Chapter 3 builds on findings of the previous chapter, by employing the seed security index and other seed security measures, to estimate the determinants of seed security and the effect of seed security on food production. Chapter 4 puts the former research in a broader context. Using qualitative evidence in the sector, this last chapter looks at seed sovereignty from the perspective of a fragile state in the context of international and national governance regimes. Overall this thesis has found that availability and social access are currently the key dimensions driving seed security status among lowland rice farmers. This is a result of high levels of poverty and a residual formal seed market, where farmers resort predominantly on their own seed and seed in their social networks, to produce rice, their major staple crop. Area owned and household labour are found to be the key determinants of seed security while results also suggest that seed security has a positive effect on rice production. This research has also found that external forces accruing from global and regional seed governance regimes are not currently undermining nor reinforcing seed sovereignty rights that lowland farmers' seem to be enjoying. However, the uneven influence between regimes might change the *status quo* towards the erosion of farmers' rights, with consequences for their livelihoods and agro-biodiversity.

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To my Mother,

Responsible for who I am today and who taught me to put always everything I have into my life endeavours

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Chapter 1. Introduction

1. Introduction

Seeds are a critical input for crop production. They have been subject to a many policies and debates as their attributes go beyond their role as a simple input (Galié, 2013; Atalan-Helicke & Mansfield, 2012; de Boef, Subedi, Peroni, Thijssen, & O'Keeffe, 2013). Seed as an input for agriculture is subject policies governing seed systems and security, food production, and rural development. Furthermore, seed is also subject to intellectual property and biodiversity policies as a result of the information embedded in its germplasm. Seed is the first input of the food value chain, and therefore whoever has rights over seed also has rights over food. Accordingly, quite a few equity issues are associated with seed, and these issues are positioned at the centre of those policies that are designed to protect farmers' rights over seeds.

Seed systems can be defined as the interrelated set of breeding, management, replacement, and distribution of seeds that serve as a means to attain food and nutrition security, income generation and the preservation of genetic heritage (Lohr, Camacho & Vernooy, R. (2015). Seed systems can also be seen as "social systems, where key practices are affected by local norms and social relationships" (McGuire, 2008, pp. 217). The informal seed sector is usually defined as being the total seed production activities of mainly small-scale farmers, wheras the formal sector refers to seed production activities in the public and commercial sector. The informal seed sector is frequently called 'local' or 'farmers' seed system(s) (Almekinders, 2000). It is estimated that in developing countries, the farmers' seed system provides more than 80% of the total food crop seed used by farmers (Dutfield, 2007).

There are four main approaches to seed in the literature, all of which have their underlying political agendas. First, the conventional approach promotes product-oriented development, with green revolution type of interventions which advocate the use of certified seed and also hybrid and improved varieties. A second approach advocates that the informal seed system is critical for ensuring farmers' livelihoods, particularly in contexts where formal markets are absent or limited. The seed security framework falls under this type of approach. The first and second approaches are useful for diagnosis purposes and more operational aspects of the seed system. However, they are disconnected from the global debate regarding farmers' sovereign rights with regards to seeds. Conversely, a third approach positions seed systems in the context of the food sovereignty movement, and it stresses the need to provide farmers with the choice to strategise and to have control over their production. Finally, a fourth approach lies in the strategic integration of formal and informal seed systems, such as the integrated seed sector approach. Based on the specific context of this study, namely the absence of a product-oriented production system and the limited presence of a formal seed sector, this study focuses on the second and third approaches, as well as related analytical frameworks underlying the informal seed system and seed sovereignty approaches.

Seed security and seed sovereignty are different concepts. Seed security "exists when men and women within the household have sufficient access to adequate quantities of good quality seed and planting materials of preferred crop varieties at all times in both good and bad cropping seasons" (FAO, 2015, pp.6). Similar to food sovereignty, seed sovereignty is embedded in broader questions of social justice and the right of farmers and indigenous communities to control their future and to make their own decisions (Schanbacher, 2010). For it is possible to possess seed security without exercising seed sovereignty.

The underlying debates and theories behind these concepts form the basis of the analysis of this thesis. Notwithstanding their differences, seed security and seed sovereignty are complementary concepts, as both provide different insights into the problems surrounding seed security and sovereignty with regards to a case study of the lowland female rice farmers' community in Guinea Bissau. This country is characterised by a context of limited statehood and a lowland production system which is dominated by women. In this context, seed security is related to the more functional aspects of seed systems, especially: seed access, availability, quality, varietal suitability, and resilience. Whereas sovereignty is an all-encompassing concept which enables the examination of the total rights that farmers have in relation to the context of seeds. This thesis builds on both the seed security and sovereignty concepts, which lead to different frameworks and theoretical strands, and bears in mind the different approaches and the particular context of this research.

2. Summary of the Literature Review

This study contributes to the literature on seed security, food security and seed governance and sovereignty in general. It also fills a large gap in knowledge on the topic of the informal seeds systems and security in Guinea Bissau in particular.

Virtually no research exists on informal seeds systems or seed security and sovereignty in Guinea Bissau. Indeed, only a few studies on the formal seed system exist, namely those carried out by the FAO and other development agencies. However, as stated in the National Seed Policy (Provisional Version) "the informal seed system is still the main source of seed for Bissau-Guinean farmers. We know little about how it works, and these are very rarely taken into account. Seed supply mechanisms for farmers, seed sources, the stability of the system over time, the varieties used, the economics and quality of informal seed multiplication and other basic information are unknown. This information is essential to better target future interventions in the seed sector" (MADR, 2015, pp. 7). The ultimate objective of this study is to fill this gap by providing the most comprehensive research to date on seed systems in Guinea Bissau, in particular for lowland rice farmers'.

This study also contributes to the body of knowledge related to the measurement of seed security (Chapter 2), the determinants of seed security, the causal relation between seed security and food production (Chapter 3), and lastly, on the interplay between seed governance and seed sovereignty (Chapter 4).

The literature on **measures of seed security is limited**. Some initial thoughts regarding types and indicators of seed security were developed in Weltzien, Remington, Sperling and De Barbentane Nagoda, (2001). More recently, Sperling and McGuire (2012) suggested the existence of indicators which are specific for evaluating seed security programmes and of projects which focus on three of the five dimensions of seed security, namely: availability, access, and quality. Largely building on the research of Sperling and McGuire (2012), the FAO (2015) suggests a number of indicators for measuring changes in each of the seed security dimensions in order to develop Seed Security Assessments in the context of relief and emergency projects. Notwithstanding the importance of moving towards an international harmonised framework to measure seed security, the set of indicators proposed in this report present some limitations with regards to measuring seed security accurately, particularly at the household level.

These limitations refer to different issues which surround seed security measurement. A first limitation is the lack of clarity regarding the level of the analysis (e.g., Weltzien et al., 2001; FAO, 2015). Indicators that appear to be aimed at assessing seed security at a regional level are mixed with household level indicators, although this distinction is not clearly stated. A second limitation is that recently-proposed indicators (Sperling and McGuire, 2012; FAO, 2015) fail to comply with the basic criteria that define a good indicator: such as being SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) or RACER (Relevant, Accepted, Credible, Easy, Robust) (OECD, 2014). The absence of definitions and units of measurement for the majority of indicators poses serious challenges for data collection, and consequently computation. Finally, a third limitation is the inability of existing approaches to the provision of a measure for providing an accurate social targeting tool for seed interventions at the household level. Current assessment indicators and targeting methods are unable to identify seed insecure households in a particular context, as they do not discern between seed-secure and seed-insecure households, neither between seed-secure and seed-insecure geographical areas, either across the dimensions of seed security, or with a single measure that simultaneously captures the five dimensions of seed security. Despite the technical issues regarding many of the FAO's proposed set of indicators, this report takes an important step towards providing a common framework for a rapid assessment in emergency contexts, by pointing out the important issues which neeed to be looked at in these contexts. However, these issues fall short of the aim to inform policy and long term seed development interventions. Accordingly, there is a gap to fill concerning the use of sound quantitative methods and the development of indicators that can help academics and practitioners understand seed systems and seed security further, which will ultimately lead to more effective seed assistance.

Despite the recognised importance of seed security for food production and security, the novelty of this concept means that little quantitative research exists on this topic. There is an extensive gap in the literature concerning: (i) quantitative evidence of the **determinants of seed (in) security,** and; (ii) the **causal relationship between seed security, food production, and food security** and also the mechanisms underlying this relationship. Several studies identify qualitative **determinants of seed security**. Chronic seed (in)security is usually associated with poverty and is more prevalent among marginal and poor farmers who experience frequent drought, poor soil quality, weak infrastructure, and limited access to land and labour (Cromwell, 1996). Disadvantaged groups, such as women-headed households, the landless, refugees, and displaced and ethnic minorities are usually the poorest and the most seed-insecure in rural communities in developing countries (GTZ & CGN, 2000). Farmers suffering from chronic seed insecurity are marginalised: i) economically - as seed insecure households are usually poor, with little land and labour available; ii) ecologically - as they usually live in areas prone to repeated drought, with degraded soils; iii) politically - as they can be placed in unsafe areas (Sperling, Remington, & Haugen 2006), and; iv) institutionally - as marginal lands typically have uncertain tenure (Haugen, 2001; Sperling et al., 2006). Despite the good qualitative coverage of factors affecting seed insecurity, there is no quantitative empirical evidence regarding the determinants of seed security. Furthemore, the causal claims between seed security and food production in academic research are exclusively qualitative, except for the varietal diversity dimension. Most of the agronomic literature covering these topics present several mechanisms through which seed security is critical for both production and production variability. Through availability and access dimensions, seed is a vital input for farmers' production and food security (FAO, 2003; McGuire & Sperling, 2011; ICARDA, 2014). The limited use of seed can lead to lowering seed rates and planted area, and can consequently reduce food production and security (Chenoune, Belhouchette, Paloma & Capillon, 2016; McGuire & Sperling, 2011; FAO/WFP[1]). Limited use can be the result of constrained availability and access, or a

[1] Myanmar (2016), Sri Lanka (2017), Central African Republic (2017), Democratic People's Republic of Korea (2013), Madagascar (2013, 2016), Mozambique (2010), Tajakistan (2011)

combination of both. On the other hand, unconstrained use is not only important for mean production at farm level, but is also instrumental for food production stability and for minimising the risk of crop failure (Chenoune et al., 2016). Seed quality has also been found to be critical for ensuring both yield (Larinde, 1997, McGuire & Sperling, 2011, FAO, 2007, Louwaars & De Boef, 2012) and yield stability (Kuivanen, Alvarez, Michalscheck, Adjei-Nsiah, Descheemaeker, Mellon-Bedi, & Groot, 2016 Louwaars & De Boef, 2012; ICARDA, 2014), and consequently food availability. Quality also contributes to food security by improving the utilisation dimension, as the quality of seeds also influences its nutritional value (Louwaars & De Boef, 2012; ICARDA, 2014). With respect to varietal suitability, farmers in situations of stress are able to use unfamiliar varieties, or non-locally adapted varieties (Weltzien et al., 2001), which can thus affect production or earnings, and can consequently contribueg to food insecurity (McGuire & Sperling, 2011). Varietal suitability is also critical for reducing production variability (Haussmann, Rattunde, Weltzien-Rattunde, Traoré, Vom Brocke, & Parzies, 2012) and for avoiding crop failure (Dominguez et al., 2004; Serraj, McNally, Slamet-Loedin, Kohli, Haefele, Atlin, & Kumar, 2011). However, food production and food security are not solely constrained by access to preferred and well-adapted varieties, for extensive quantitative evidence exists on the effect of the loss of variety diversification on food production (Di Falco & Chavas, 2007; Di Falco & Chavas 2009; Di Falco, Bezabih & Yesuf, 2010; Di Falco & Chavas 2008, Smale, Hartell, Heisey, & Senauer, 1998, Widawsky & Rozelle, 1998). Apart from the estimation of varietal diversity on food production, virtually no quantitative evidence exists regarding the potential effect of seed security on food production.

Finally, the interplay between **seed governance and seed sovereignty** is still a relatively understudied topic. There are very few case studies in the literature which focus on interactions between the regulatory space which is brought about by international obligations and frameworks regarding the domestic seed legislation and its implications for farmers' rights (e.g., seed-specific farmers' rights: Atalan-Helicke and Mansfield, 2012; Galié, 2013; Tripp et al., 2007; Srinivasan, 2003; Wattnem, 2016). There are even fewer examples where the analysis goes as far as the level of farmers' *rules in use*, which provide insights into how these policies and laws can affect *rules in use* by farmers (Galié, 2013). Furthemore, in this context, most research has focused on intellectual property rights (IPR) laws which apply to seeds by privatising germplasm, while the role that the non-IPR-related seed laws related to seed enclosure might play on farmers' rights is relatively unexplored (Wattnem, 2016). Finally, virtually no research exists which provides evidence of how limited statehood can shape these specific processes.

3. Study Site and Data Collection

This study focuses on rice-producing areas in Guinea-Bissau. Rice has long been the main staple food in many traditional rice growing communities and in major cities in West Africa, and Guinea-Bissau is no exception. From the early 1970s, rice has been the main source of caloric intake in West Africa (Chuhan-Pole & Angwafo, 2011). Nearly 56% of the rice consumed in Guinea Bissau is a result of farmers' own production (WFP, 2016) and rice consumption per capita is one of the highest in Africa, with an average of 86 kg per capita per year (Dawe, 2010).

There are three main rice production systems in Guinea Bissau: Mangrove (salt water), Irrigated, and Rainfed (both Upland and Lowland). This thesis focuses on the Lowland rainfed production system in Bafatá, which is located in east Guinea Bissau. Lowland rice production is the principal economic activity for the majority of the region's women, followed by horticulture. Despite men having a minor role in some lowland production tasks, women are those who exercise control over the land in terms of the inputs and outputs of rice production. Similar to many developing countries, female farmers are disproportionately engaged in producing staple crops, while men are predominantly involved in cash crops. Nonetheless, perhaps as a result of many international and local development projects[2], the diversity of women's livelihoods has broadened, mainly as a result of the promotion of horticultural crops, which virtually constitute the sole cash crop production for women, supplementing their work in producing the staple crop of rice. Despite the irrigation potential for lowland rice production in the region in general, and Contuboel in particular, rain-fed lowland is the predominant rice production system in the Region. Contuboel is particular relevant as a study site, not only because research in the lowland production system is virtually inexistent, unlike other agricultural rice production systems such as the Mangrove, particularly in the southern Guinea-Bissau (e.g., Temudo, 2011; Temudo & Abrantes, 2013; Temudo & Cabral, 2017), but also for its relevance from a political perspective. Bearing in mind its high potential for the production of lowland rice, the Africa Rice Center and Ministry of Agriculture Africa Rice Centre (AfRC) have defined the Contuboel rice-growing sector as being part of the lowland rice "hub"[3] in Guinea Bissau, along with Bafatá.

[2]It is difficult to tell whether this development would have happened without aid.
[3] The strategic geographical area of intervention for Africa Rice Centre

Notwithstanding its strategic importance, the development of the lowland rice seed market in Guinea Bissau is virtually inexistent. The formal sector is reduced to the national research system, where INPA-Contuboel - the region's main research institution, acts more like a commercial seed producer than as a breeder, as is to be expected by its mandate. There are virtually no formal producers, breeders, or traders for this production system. The majority of lowland agro-ecological system farmers rely on their own production and on their social networks to source new seeds, or seeds for planting, in case of need (see Chapter 2 and 4 for details on seed market development)

Guinea Bissau's context of lowland rice production provides a suitable setting for researching into seed security and for exploring the relationships between gender, food production/security, and seeds. Rice is the main staple crop in Guinea Bissau, with 75.2% of households being engaged in rice production. The annual average production level is 962 Kg per household, of which 70% is for own consumption, 10% is saved, and approximately 5% is distributed to close family members. About 56% of consumed rice originates from their own production, while 42% is bought on the markets (WFP, 2016). Lowland rice production mainly takes place in the east of Guinea Bissau, where farmers are predominately female (Oliveira, Havik, & Schiefer, 1996). The lowland tenure arrangements are defined by the social organisation of Tabancas[4], which grants customary rights over land to women (Bruce, Moura, & Tanner, 1992; Oliveira et al., 1996). As such, women have the most prominent role in the lowland rice production process, and are responsible for practically all activities, except the land clearance and soil preparation tasks. The numbers of wives within a household, the number of children, and the number of grown-up sons and their wives all determine a household's size, and consequently a household's wealth and productive capacity (Bruce et al., 1992). With particularly regard to seed management, sowing is mainly carried out by women and is guided by the older woman of the household, who has the responsibility for choosing the cultivation sites according to the vegetative cycle of each of the varieties that they intend to produce and the characteristics of the soil. During harvest, women first cut the larger panicles, selecting the best for use during the next sowing season, and the remainder of the harvest is saved for household consumption (Oliveira et al., 1996). Women's roles in the cultivation and seed-saving of rice place them at the forefront of assuring

[4] "Tabanca" is a village which is formed by one or several *moranças.* A *morança* is most often used to distinguish between the residential areas of the different extended families or lineages in each *tabanca*. Within a *morança* – where the basic organisational unit is the fogão (stove), which approximates to a nuclear family of two or more generations sharing the same cooking place.

seed and food security in the east region of Guinea Bissau (see Chapter 4 for more details on rules used by women on seed management and use).

Data Collection Methods

Data used in Chapter 2 and 3 were collected through a survey of farmers in the Contuboel sector. This survey focused on three main aspects: i) Household and farmers' demographic and socio-economic characteristics; ii) Farm and agricultural production, and; iii) Seed Security characterisation. A total of 351[5] households were interviewed between February and March 2015, immediately after the harvest period and before the sowing period of the following rainy season. Furthermore, I conducted six (6) interviews with seed-related organisations[6] which work at the regional level; six (6) focus group meetings with both female and male farmers, and; 16 individual interviews (eight female and eight male farmers) with the objective of obtaining disaggregated information on upland and lowland productions systems. Qualitative research had the twofold objective of preparing the survey questionnaire and of collecting qualitative data regarding the seed system and seed security issues.

A household is defined as being the basic organisational unit, which is locally referred to as a *fogão* (stove), which approximates to a nuclear family of two or more generations sharing the same cooking place. A typical household is usually constituted by the male head, his wife(s), and their daughter(s) and son(s). The older the male head is, the more likely he is to have more wives. One of the objectives of this survey is to collect gender-disaggregated data and consequentky the interviewing method utilised recognises intra-household dynamics - particularly the dynamics of polygamy and the gendered division of labour and land tenure across the two main production systems - rainfed lowland and upland (for more detail on access to and control over land and division of labour by gender, please read Chapter 4). To this end, the "Household and farmers' demographic and socio-economic characteristics" section of the interview was carried out with the household head, with the support of other family members who contributed to the more specific information whenever necessary. With respect to "Farm and agricultural production" and "Seed Security characterisation", these were both broken down into two sub-sections: lowland and upland. For the lowland sub-section, each woman in

[5] From the 351 interviews, 41 were not included in the data set because they were not involved in lowland rice farming that year. The sample size was increased to allow for non-response, refusal, and households that were not engaged in lowland farming, in order to ensure a confidence level of 95% and margin of error of 5%.

[6] Regional Directorate of Agriculture, National Research Agricultural Research Institute INPA- Contuboel Research Center, Guiarroz (NGO), Proagri, APALCOFE, Agro-Multipliers Association.

the household who was responsible for one or more plots was interviewed, providing specific information about those plots, while the same approach was employed for men, to obtain information regarding upland plots. This approach enabled the construction of sex-disaggregated variables, such as income or livestock value.

In addition to this qualitative and quantitate data, Chapter 4 also gathers information through interviews with key informants, covering specific issues regarding seed sovereignty in Guinea Bissau and extensive document analysis and literature on the topic (for details on data collection for this chapter see Chapter 4 - Section 2).

Map 1. Map of Guinea Bissau (Legend: shaded square indicates the study area)
Source: http://www.un.org/Depts/Cartographic/map/profile/guineabi.pdf

Regarding the sampling strategy, a self–weighting, two-stage cluster sampling design was employed, where each unit at the final level has the same probability of being selected. Specifically, a two-stage sample from a population of villages of different sizes was carried out, using a simple random sample of 20 villages for the first stage and for the second stage, in each village, a number of households proportional to the size of that village were also randomly selected. The overall sample size was 310 Households[7], with an average sample per village of 15, with a confidence level of 95%, and a margin of error of 5%.

4. Research Motivation and specific objectives

The overall objective of this research is to fill the above-mentioned extensive knowledge gap which exists regarding seed systems, security, and governance in Guinea Bissau. Within this overall objective, this study aims to address various specific aspects. First, to demonstrate the critical role of women as food providers, innovators, and stewards of agro-biodiversity of rice in the east region of Guinea Bissau. Secondly, this research is also motivated by the limited understanding of issues regarding farmers' seed system, seed security, and seed sovereignty in Guinea Bissau, and how this knowledge gap can undermine the development of relevant interventions in the seed sector, with unintended consequences for household's food security. No comprehensive study exists on seed systems in Guinea Bissau. Finally, this study aims to contribute to the knowledge and understanding of the fields of seed security and seed sovereignty more generally, towards creating more effective policies and interventions and moving forward the academic fields of research which are covered here.

More specifically, this study aims to contribute to the literature on seed systems, seed security, and sovereignty through the following research objectives.

The **main research objective of Chapter 2** is to develop a comprehensive seed security measure - the Seed Security Index, in order to address the shortcomings identified in the literature review, in particular by bringing a broader understanding of the Guinea Bissau seed systems and seed security, as well as supplying a tool for a more effective targeting approach to seed interventions. It is worth mentioning that the main purpose of this index is not that it is designed to be used for cross country comparison, but rather mainly for development planning and targeting purposes within a particular area - such as a country or a region. For example, employing the same methodological approach at a larger scale, such as country level, would provide data forintra-country comparisons, namely through region or village level rankings, enabling the mapping of seed security, as well the characterisation of different seed security profiles and the identification of the most seed insecure households in a particular context. This

[7] This is the final sample, as from the 351 interviews, 41 were not included in the data set because they were not involved in lowland rice farming that year. The sample size was increased to deal with this kind of issue and to ensure an adequate confidence level and a margin of error.

index will summarise in a single measure the five dimensions of seed security at the household level, namely: access, availability, quality, varietal suitability, and resilience. Since rice is the main staple food in Guinea-Bissau and guaranteeing its seed security might have an instrumental role in household's food production and security (n.b., this will be tested in Chapter 3), this paper constructs a Seed Security Index (SSI) in the context of the rice lowland production system. The key method employed to compute the index is principal component analysis with polychoric correlations. Once replicated and tested elsewhere, this approach to measuring seed security stands to serve as a tool for supporting governments, and agricultural organisations in particular, elaborate policies, and formulate and target interventions in the seed sector.

The research objective of **Chapter 3** is to gain a deeper understanding of the mechanisms underlying seed security, and its relationship with food production and security, by answering the following research questions: (i) What are the **determinants of seed security**?; (ii) What are the **mechanisms underlying the relation between seed, food production, and food security**? and; (iii) What is the **effect of seed security on food production**, and consequently on food security? The determinants are estimated through three specifications models: Ordinary Least Squares, Village level Fixed, and Village level Random Effects. To examine the mechanisms underlying the relation between seed, food production, and food security, an in-depth literature review was carried out. Finally, to estimate the effect of seed security on food production, a generalised propensity score matching approach is taken to estimate a dose-response function in the context of a continuous treatment variable - the index of seed security.

Chapter 4 contains the research objective of contributing to a broader and more comprehensive understanding of the Guinea Bissauan lowland socio-ecological seed systems and to identify the potential challenges and opportunities brought about by global and regional policies and laws for female farmers rights' in this context. This objective is achieved by answering the following research questions: (i) What are the international and regional seed governance regimes that characterise Guinea Bissau's seed related laws, being a country which is characterised by fragility and limited statehood?; (ii) What rules and rights emerging from these systems are affecting, or are likely to affect lowland female farmers' rights, with consequences for agrobiodiversity and food security? The research hypothesis of this paper is that the Plant Variety Protection (PVP) and Regional and Harmonization agendas have a detrimental effect on the rights currently enjoyed by farmers with respect to seeds, while the international governance system focusing on farmers' rights and biodiversity reinforces these rights. This hypothesis is tested by using the Socio-Ecological Systems framework as the analytical framework for analysis, which is a recent outcome of Ostrom's Institutional Analysis and Development (IAD) framework.

The thesis is organised in the following manner:

Chapter 2 contributes to the literature on seed and food security, in a first attempt to develop a comprehensive measure of seed security. In the context of rice lowland production systems in Guinea Bissau, this chapter presents a Seed Security Index, which aims to capture the many different dimensions of seed security in a single measure. The objective is to develop a strong and practical tool for decision making for seed security interventions in both development and emergency contexts.

Chapter 3 builds on the findings of the previous chapter, by using the seed security index and other seed security measures, in order to estimate the determinants of seed security and its effect on food production.

Chapter 4 aims to provide a more holistic view of the seed sector in Guinea Bissau, by characterising the seed governance and system situation in Guinea Bissau, and by examining the risks and opportunities of the international/regional legal and institutional frameworks on the robustness of the system, while placing the previous chapters in a broader context.

Finally, Chapter 5 summarises the major findings and recommendations of my work, and presents recommendations for future research.

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Chapter 2. Seed Security among Lowland Female Farmers in Guinea Bissau

This chapter aims to contribute to the literature of seed and food security as a first attempt to develop a comprehensive measure of seed security. In the context of rice lowland production systems in Guinea Bissau, this chapter presents a Seed Security Index intended to capture in a single measure the many different dimensions behind seed security. The objective is to develop a strong and practical approach for decision making around seed security interventions in both development and emergency contexts.

List of Maps, Figures and Tables

1. Introduction

Seed security is instrumental to farmers' livelihoods. Seeds are one of the most critical inputs in agricultural production (GTZ & CGN, 2000; Wekundah, 2012) and seed vulnerability can severely affect farmer welfare (Sperling, Remington, & Haugen 2006). Seed security is also instrumental for sustainable agricultural development (GTZ & CGN, 2000) and is vital for ensuring food security for the rural population (Longley, Dominguez, Saide, & Leonardo, 2002; McGuire & Sperling, 2011; Wekundah, 2012; Sperling, & McGuire, 2012).

Seed security definitions have evolved over the last two decades to reflect a broader understanding of the seed security dimensions. The Food and Agriculture Organisation (FAO) defined seed security as being "access by farming households to adequate quantities of good quality seed and plant materials of adapted crop varieties at all times, both good and bad" (FAO, 1998a, p. 187). McGuire and Sperling (2011) argue that these definitions, which are based on notions of universality, access, sufficient quantity, and quality are more adequate for the context of defining rights, than for looking for possible gaps in seed security. Alternatively, a set of definitions developed by Remington et al. (2002) based on USAID's food security framework (1995) are thought to be more useful as a diagnostic tool for seed security assessment. Their definitions specify several key dimensions of food/seed security, namely: availability, access, and utilisation. Following this research, Webb and Rogers (2003) added a fourth dimension - risk, to represent food insecurity when households cannot buffer shocks that affect any of the above elements. McGuire and Sperling (2011) re-named this dimension in the context of seed security as *resilience*.

Inspired by the USAID Food Security Conceptual Framework (1998), the FAO developed the Seed Security Conceptual Framework (SSCF), which comprised three dimensions: seed availability, seed access, and seed quality. The underlying concept of quality under this framework was an all-encompassing dimension which replaced what had previously been named as Utilization – aimed to capture both seed quality and farmers' preferences in terms of varieties. More recently, following a gathering of experts in 2013, the FAO (2015) responded to the shortcomings mentioned above by extending the number of dimensions of seed security and by recognising intra-household dynamics, whereby "household" was replaced with "men and women". The FAO definition now reads - "Seed security exists when men and women within the household have sufficient access to quantities of available good quality seed and planting materials of preferred crop varieties at all times, in both good and bad cropping seasons" (FAO 2015, p.2). The FAO disaggregates this functional definition into five discrete dimensions which are considered to be critical for seed security: 1) seed availability (seed supply at the right time and place); 2) seed access (means to acquire); 3) seed quality (germination, physical purity, free from pests and diseases); 4) varietal suitability (adapted crop varieties farmers prefer and need), and; 5) stability of seed system in the context of shocks and stresses (resilience).

Underlying the FAO's seed security definition above is the understanding that men and women in the same household can have a different status with respect to seed security. A large body of the literature demonstrates that men and women farmers have different responsibilities in agricultural production systems, particularly in the case of rice farming (FAO, 2004). Accordingly, in a review of 24 empirical studies, Peterman, Behrman and Quisumbing (2014) found sound empirical evidence that women have less access to essential productive resources such as fertilizers, pesticides (FAO, 2004; Doss & Morris, 2001; Meinzen-Dick, Quisumbing, Behrman, Bjermavr-Jenzano, Wilde, Noordeloos, & Beintema, 2011) and particularly seeds (Doss & Morris, 2001; Kinkingninhoun-Mêdagbé, Diagne, Simtowe, Agboh-Noameshie, & Adégbola, 2010). These gender gaps undermine agricultural productivity (Udry, 1996; Goldstein & Udry, 2008; Croppenstedt, Goldstein, & Rosas, 2013) and subsequently obstruct poverty reduction (Meinzen-Dick et al., 2011). There is also evidence that disadvantaged groups, such as households headed by women are usually the poorest and the most seed-insecure in rural communities in developing countries (GTZ & CGN, 2000). According to the report of the World Bank, the FAO, and IFAD (2009) on "Gender and Agriculture", gender-sensitive seed governance is believed to enhance women's seed sovereignty by improving their ability to access and control seed in ways which are commensurate with their roles as food providers and producers and as preservers of food cultures. Accordingly, it is expected that seed security status will differ among male and female farmers, due to the fact that gender differences exist in the seed security dimensions.

At the household level, households can be classified into different categories with respect to seed security. According to David (2001), households can be divided into three groups: i) *Seed-secure households* that primarily depend on farm-saved seed and rarely face seed shortages; ii) *Regularly seed-insecure households* that run short of seed once a year or once every two seasons, and; iii) *Chronically seed-insecure households* that depend on off-farm sources every season. Longley et al. (2002) provide a similar classification of household seed security, which is based on wealth groups: i) *Seed-secure households* have sufficient resources at their disposal to grow and access seed, and to experiment with new varieties; ii) *Crisis-prone households* may become seed insecure in the case of stress events, such as droughts, and iii); *chronically seed-insecure households* are less endowed farmers that continuously face difficulties in accessing good quality seed.

As a consequence of these different forms of marginalisation, the informal seed sector is a key source of seeds for many farmers in developing countries. The informal seed sector can be defined as 'seed production activities that are mainly in the hands of farmers, usually small-scale farmers'. Conversely, the formal seed sector refers to 'seed production activities managed primarily by the public and commercial sector' (Almekinders, 2000). The informal seed sector is also labelled as 'local' or 'farmers'' seed system(s)' (Almekinders, 2000). Scholars are increasingly recognising the importance of the informal seed sector for ensuring seed security. Estimates indicate that the great majority of seed planted in developing countries is produced by farmers in the informal seed sector (GTZ & CGN, 2000; Loch & Boyce, 2003; McGuire, 2008; McGuire & Sperling, 2015). Despite considerable investment in formal seed sectors by development organisations and governments, this sector has not yet been able to effectively respond to farmers' needs in developing countries (Cromwell, 1996; GTZ & CGN, 2000; Tripp, 2001; Neate & Guei, 2010). This arises from the fact that the formal seed sector offers a limited range of varieties and operates within specified quality standards, with a low ability to meet the diverse needs of farmers and to address complex environmental stresses (GTZ & CGN, 2000; Ravinder, Tonapi, Bezkorowajnyj, Navi, & Seethrama, 2007; Lipper & Cooper, 2009; Cavatassi, Lipper, & Narloch, 2011; Tittonell & Giller, 2013; Coromaldi, Pallante, & Savastano, 2015). Accordingly, new varieties are genetically uniform and have been developed for highly responsive simplified monoculture systems (Smale, 2005; Perrings et al., 2006) which are expected to outperform local varieties if accompanied by the simultaneous use of complementary inputs, such as fertilizers, pesticides, and labour (Narloch, Drucker, & Pascual, 2011; Teklewold, Kassie, Shiferaw, & Köhlin, 2013; Suri, 2011). Conversely, local varieties provided by the informal seed system are the result of an *evolutionary* selection process (Altieri, 2004) which has been accomplished over generations of natural and deliberate selection of valuable genes that confer resistance to biotic and abiotic stresses (Newton, Akar, Baresel, Bebeli, Bettencourt, Bladenopoulos, & Koutsika-Sotiriou 2010; Berg, 2009; van Etten, 2006; Mokuwa, Nuijten, Okry, Teeken, Maat, Richards, & Struik, 2014). These features are extremely important in the context of the expected consequences of climate change in agriculture (Newton et al., 2010; Mercer, Perales, & Wainwright, 2012; Coromaldi et al., 2015). Nevertheless, the promised benefits of the formal sector have not been fully put to the test, as strict policies and regulations, poor organisational arrangements, and inadequate infrastructure have all contributed to the weak formal system in developing countries (Ravinder et al., 2007). Despite the different and often conflicting philosophies that have shaped seed sector development (McGuire & Sperling, 2015), ranging from more formal to informal initiatives for promoting seed systems, recent trends are for an increasing call for a more 'integrated seed sector' approach (Almekinders & Hardon, 2000; Louwaars & De Boef, 2012).

The literature on measures of seed security is limited. A working group on "Targeted Seed Aid and Seed-System Interventions: Strengthening Small Farmer Seed Systems in East and Central Africa" (Weltzien, Remington, Sperling, De Barbentane Nagoda, & others, 2001)[8] presented some initial thoughts on types and indicators, in a first attempt to develop indicators for measuring seed-system stress. Sperling and McGuire (2012) suggest a number of indicators for evaluating the effects of seed security programmes and projects on improving farmers' seed availability, access, and quality. These authors propose different sets of indicators for each dimension of seed availability, access, and quality. Building on the research of Sperling and McGuire (2012), the FAO (2015) report suggested sets of indicators for measuring changes in each of the seed security dimensions in order to develop Seed Security Assessments in the context of relief and emergency projects.

The existing measurements of seed security have several limitations in. First, the level of the analysis is often not clear, with household and geographical level indicators often being mixed-up in individual studies. Weltzien et al. (2001) present some ideas regarding possible indicators designed to measure seed-systems stress, however most, but not all of the indicators presented are at the household level. This is also evident in the case of the FAO's (2015) indicators, which combine household level and more regional/system level indicators for the assessment of each dimension. From the perspective of the literature on ecosystem health, McGuire (2001) argues for the need to clearly set out different levels of assessment, moving from household indicators to a direct measurement of small parts of systems, and from there to more aggregated levels that measure overall system performance. The measurement of seed security would benefit from a similar approach which clearly distinguishes between levels of analysis. Almekinders (2001) recognises different levels of analysis, ranging from household to community through to national levels, but falls short of providing clear proposals of how indicators and measures should vary according to the different levels of analysis of the seed system. The second limitation can be seen from a technical perspective. In the context of development practice, to qualify as a good indicator, such an indicator has to conform to certain criteria - such as being SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) or RACER (Relevant, Accepted, Credible, Easy, Robust) (OECD, 2014). However, many of those indicators proposed recently in Sperling and McGuire (2012) and by the FAO (2015) fail to comply with many of these criteria. The majority of those indicators proposed are not specific in their definition, nor measurable, as most of them do not present the unit of measurement, neither are they clear on how this measurement is computed. Furthermore, is not clear whether certain indicators need to be quantified (quantitative

[8] Who originated from 14 institutions (drawn from IARCs , NARS, and NGOs) and worked together from June 21-24, 2000 in Kampala, to compare and contrast practical experiences of supporting farmers' seed systems, particularly in times of severe stress

indicator) or described (qualitative indicator). A third major limitation of existing approaches to measure seed security relates to the issue of the planning and social targeting of seed interventions, in both development and emergency contexts. Current assessment indicators and targeting methods are mainly focussed on the context of emergency and do not discern between seed-secure and seed-insecure households, neither between seed-secure and seed-insecure geographical areas, nor even across seed security dimensions or with a single measure that simultaneously captures the five dimensions of seed security. Accordingly, there is great need to develop standard quantitative indicators and methodological approaches for international use that can help academics and practitioners easily capture information at different levels of analysis and also enhance our ability to plan and target interventions where insecurity is greatest.

There is growing interest in the use of composite indicators as analytical tools to inform and prioritise policies Composite indicators are now being applied in many research areas to measure different phenomena, such as: food security (Demeke, Keil, & Zeller, 2011, Wineman, 2016; Beegle, Galasso, & Goldberg, 2017); environmentally-related beliefs and behaviour (Clements, 2012); socio-economic status (Filmer & Pritchett, 2001; Vyas & Kumaranayake, 2006; Kolenikov & Angeles, 2009); intermediary determinants of early childhood health (Osorio, Bolancé, & Alcañiz, 2013); agriculture (Gómez-Limón & Riesgo, 2009; Gómez-Limón & Sanchez-Fernandez, 2010); gender inequality (Jütting, Morrisson, Dayton-Johnson, & Drechsler, 2008), and; institutions (Branisa, Klasen, & Ziegler, 2009).

An important question to raise is: What are the merits of using a single multidimensional measure over a single indicator? Drawbacks may exist from combining different indicators into one score, particularly when attempting to understand the determinants of seed security and the channels of impact. In the context of poverty indexes, Ravallion (2011a) points out that because poverty is multidimensional, the value of a single index for policy-making is not immune to scepticism. An international meeting on the measurement and assessment of food deprivation concluded that there is no "perfect single measure that captures all aspects of food insecurity", however the usefulness of composite measures was not discarded. Accordingly, the main advantage of having an index is that it better reflects a comprehensive view of a phenomenon that cannot be captured by just one component (De Muro, Mazziotta, & Pareto, 2011; Žítek & Klímová, 2015; Rickels, Dovern, Hoffmann, Quaas, Schmidt, & Visbeck, 2016). Furthermore, an index allows for a meaningful ranking of different regions, or households in terms of the severity of seed insecurity, and also enables the carrying out of statistical analyses to determine the effects of different variables on the overall outcomes of households. Such an exercise can help better target resources to those who are most in need and can also track changes over time (Wineman, 2016). According to Ravallion, the development of a composite indicators requires paying attention to four main issues: (i) the need for conceptual clarity on what is being measured; (ii) the need for transparency regarding the trade-offs embedded in the index; (iii) the need for robustness tests, and; (iv) the need for a critical perspective of policy relevance (Ravallion, 2011b). To avoid the recurrent mistakes of previous research on composite index construction, this study takes into account all of these issues, as detailed in Section 4, and it also carries out an additional analysis with alternative indices which aims to overcome some of the problems of a single measure.

The **main research goal of this paper** is the computation of a Seed Security Index and the utilisation of this index to carry out an in-depth analysis and provide insights into the profiles of seed insecurity in the study area. Nevertheless, intermediate outcomes arise from this paper's research process. The econometric analysis carried out serves to assess the internal dynamics of seed security, to unravel trade-offs between different seed security variables, and to derive measures that will ultimately serve as a targeting tool for seed interventions in particular contexts, at a certain point time, and in a targeted geographical area. It is thus worth pointing out that the purpose of the construction of this index is not to achieve the policy goal of serving as a rank-based indicator, such as the Multidimensional Poverty Index (Alkire & Santos, 2010) or the Global Food Security Index (GFSI) (Economist Intelligence Unit, 2013). The proposed approach can rather be categorised under the category of context-specific indexes. Examples of similar approaches applied to different contexts include: the asset indices commonly used to proxy for Socio-economic status to identify and target poor people (e.g., Filmer and Pritchett, 2001; Sahn and Stifel, 2003); the recently-proposed Augmented Asset Index (Ngo & Christiaensen, 2018); the livelihood security index which is to be used as a tool for development planning (Singh & Hiremath, 2010), or; the socio-ecological vulnerability indices for producing vulnerability maps for identifying priority areas of concern (Abson, Dougill & Stringer, 2012). Furthermore, the World Food Program extensively uses multivariate analysis, particularly Principal Component Analysis, as a way of defining profiles of food security in specific regions or countries in the context of vulnerability analysis and mapping (e.g., WFP, 2006; WFP, 2014; WFP & UNICEF, 2017). In summary, the general approach is context-independent, although, however, the components and respective weights are context-specific. Therefore, it is more appropriate to consider the Seed Security Index to be an approach for a measure, rather than a measure in itself. Accordingly, in order to address the shortcomings identified in the literature review, I have developed a comprehensive Seed Security Measure based on SMART indicators- called the 'Seed Security Index', which will ultimately serve as a planning and targeting tool for seed interventions, thus allowing the researcher to gain a deeper understanding of the dynamics of seed security throughout the process in the study site context.

The **underlying hypothesis** of this analysis is that the phenomenon to be measured—seed security, can be used in a particular location to identify household and farm characteristics that are associated with seed insecurity. The **research questions** are: (i) does the proposed set of indicators to be used to construct the index explain the seed security phenomena in the context of Guinea Bissau?; (ii) which dimensions and indicators of the seed security index have a more prominent role in explaining the phenomena of seed security in Guinea Bissau?; (iii) which household and farm characteristics associated with seed insecurity can be used to increase the predictive power of vulnerability going forward and to improve readiness for support.

In order to answer the research questions in detail, I collected **survey data** to construct the index. The data were collected from a survey of households carried out in Guinea Bissau in 2015, covering 310 female farmers who produce rice, using the lowland production system. The variables I have used in the index were purposely selected to represent the five different dimensions of seed security.

One key **methodological** decision made during the index-construction process is the weighting technique. Methods of aggregation can be grouped as being "positive", or endogenous and "normative", or exogenous (JRC-EC, 2008; Gómez-Limón & Sanchez-Fernandez, 2010). With positive techniques, the weights of the base indicators are obtained via statistical procedures, whereas with "normative" techniques, weights are defined according to the opinion of experts and external decision-makers[9]. In this paper, two approaches are employed: i) PCA with categorical variables, and; ii) PCA using polychoric correlations. PCA features among positive methods[10], and is one of the chief statistical techniques used in the construction of indices (Demeke et al., 2011, Wineman, 2016; Beegle et al., 2017; Filmer, & Pritchett, 2001; Vyas & Kumaranayake, 2006; Kolenikov & Angeles, 2009; Osorio et al., 2013; Gómez-Limón & Riesgo, 2009; Gómez-Limón & Sanchez-Fernandez, 2010). The reasons for choosing a positive approach over a normative are the following: i) first, adopting a positive approach is a way of selecting and aggregating variables without making *a priori* assumptions regarding the weighting scheme (Lockwood, 2004; Njong & Ningaye 2008); ii) secondly, as the weights are assigned endogenously, based on patterns in the data, this has the advantage of being less prone to criticism regarding the possibility of researchers or other stakeholders being biased in their assignment of weights (Sharpe & Andrews, 2012), iii) finally, Seed Security is not a social construction, unlike sustainability or well-being for example, and therefore it is not as important to take into account society's preferences when assigning different levels of importance to different variables in the composite indicator. Nonetheless, in the context of a sensitivity analysis, I also use equal weighting,

[9] Examples of normative methods include: Analytic Hierarchy Process (AHP), direct assignment of points, trade-off weighting, and the SMART method (JRC-EC, 2008)
[10] Other positive methods include: data envelopment analysis (DEA) and regression analysis (JRC-EC, 2008)

which is neither a normative nor a positive method, in order to test the sensitivity of the index to different weighting schemes. The main advantage of this approach over the other approaches is that it is more transparent and simple, and therefore is easily understood. However, if variables were to be grouped into identifiable *dimensions*, and then aggregated into the composite index, in this case equal weighting could imply an unequal weighting of the dimension in the final aggregation. This could result in the index having an unbalanced structure (JRC-EC, 2008; Sharpe & Andrews, 2012).

The use of multivariate analysis approaches as a weighting method, such as PCA, also provides other valuable contributions to the understanding of seed insecurity dynamics in the study site. First, it provides information regarding the structure of the data, by showing how the different variables relate to each other and by uncovering different forms of seed security as well as the trade-offs between the different seed security variables for the particular context of the study site. Secondly, albeit acknowledging that the generation of a single composite of seed security has the downside of potentially hiding important information regarding the relationships between the original variables, the principal component scores with the highest variance of this context-specific information are also used as seed security indexes, representing different types of seed security to those found in the aggregated index.

Additionally, to explore the role that intra-household gender dynamics might play a role in influencing seed security, and based on the fact that female farmers predominantly produce in lowland cultivation, two different sets of variables are analysed: Ungendered and Engendered[11]. Gender is an important dimension in food security (Quisumbing, 1995; the World Bank et al., 2009; the FAO, 2013; ADB/FAO, 2013; Kassie, Ndiritu, & Stage, 2014) and it is undoubtedly an important determinant of seed security (Louwaars, 1994; Sperling, 2001; McGuire, 2008; the World Bank et al., 2009; Sperling & McGuire, 2012, Galiè, 2013). Women in developing countries often carry out key roles in seed system processes, such as seed selection, storage, and exchange (Sperling, 2001; Louwaars, 1994; Galiè, 2013) and this is particularly relevant in Guinea Bissau. Accordingly, in the lowland rice production context, women take the lead in virtually every process in the lowland rice seed production system. In order to capture these dynamics, I analyse two different sets of variables: i) "engendered": where gender-specific variables were introduced when applicable (e.g., female-owned assets), and; (ii) "ungendered": where household level variables are not disaggregated by sex (e.g., household-owned assets). "Engendering" the index has the ultimate goal of exploring whether including gender-specific variables contributes to enhancing index reliability and robustness, while simultaneously providing

[11] Definition: "formulation of concepts and definitions used in data collection that adequately reflect the diversity of women and men" . . . . "and capture all aspects of their lives" (Hedman, Perucci, & Sundström, 1996)

evidence (or not) that gender-specific data can have a better explanatory power for some phenomena than household aggregated data. Such information is vital for informing policy and decision-makers and for enabling advances towards intra-household seed security dynamics with better design interventions. Overall, the question to be answered is: are gender-specific household level variables as equally good as gender-specific indicators in describing the seed insecurity of an extremely engendered production system, such as lowland rice production?

This paper provides a methodologically-sound approach to providing a greater understanding of seed systems and seed security in the context of the rice lowland production system, which ultimately leads to more effective seed-related development interventions. This is particularly relevant, as rice is the basic staple food in Guinea-Bissau, and thus guaranteeing its seed security could well have an instrumental role in increasing households' food production and security (this hypothesis will be tested in Chapter 3).

This study has found that, overall, the proposed set of indicators presented in this study do, indeed, capture the different dimensions of seed security. In particular, the variables captured by the first component of Biodiversity and Social Capital together with the second component of and Availability, Social Access, Utilisation (quality and varietal suitability) represent approximately 50% of the variance in the data. The third and fourth components of Short and Long-Run Wealth account for the other 50%. However, the first two principal components, which individually also serve as seed security indices, are those that best explain seed security for lowland rice varieties in Guinea Bissau. Notwithstanding the role of endowment-related variables (such as those represented by the third and fourth components) in promoting access and resilience-related seed security, the absence of a seed market prevents farmers from experiencing this type of seed security. Nevertheless, the Seed Security Index that I have constructed provides a measure which can be used to identify those farmers who simultaneously perform badly across all seed security variables, which is relevant from a policy perspective. This paper also found two complementary, more context-specific types of seed security, which are represented by the alternative indices, namely: (i) the biodiverse, marginal environment, and aid recipient type of seed-secure farmer/area, and; (ii) the type of seed-secure farmer/area that experiences unconstrained availability, is more socially connected to seed organisations, and works with seeds of greater quality and more suitable. This paper also shows how the socio-economic and farm characteristics of seed-insecure farmers vary according to the seed security measure being used. Overall, the key policy implication of this chapter is that each measure reflects different seed security issues as well as different farmers' profiles, and consequently each measure requires different types of intervention.

The chapter is organised as follows. Section 2 presents the Case Study, with a brief description of the country and regional context and then goes on to present descriptive statistics on farms and farmers. Section 3 is devoted to an explanation of the methods used to construct the SSI. Section 4 presents the results, namely: (i) a seed system analysis which examines single indicators for the different dimensions of seed security; (ii) a Multivariate analysis to explore the structure of the data, (iii) the weights retrieved by PCA analysis, showing how different indicators and dimensions contribute to the single seed security measure, (iv) a ranking of villages, based on Seed Security index scores, and finally; (v) a Descriptive analysis, where sample households are classified into relative seed security groups and differences between the more and the less seed-secure groups are assessed. Section 5 contains a discussion on the results and conclusions are drawn.

2. Descriptive Statistics

This section will provide some descriptive statistics covering farmers', farms and seed security characteristics. **Table 1** below shows descriptive statistics from the collected sample of the farmers and farms in the Contuboel sector. In line with other countries in West Africa (e.g., Gambia, Côte d'Ivoire, Guinea Conakry) the majority of lowland farmers are female (98%). The average age is 32 years old, and most of the farmers had no form of formal or religious education. Indeed, just nine per cent of farmers had gone to primary school.

Table 1. Lowland Rice Production Systems and Rice Farmers Characteristics

	Mean	Std. Dev.	Min	Max
Low land farmer characteristics (n=1083)				
Gender of lowland farmers				
Male	1.84%	-	0	1
Female	98.16%	-	0	1
Age of lowland farmers	32.68	14.23	7.00	90.00
School level of lowland farmers				
None	88.28%	-	0	1
Koranic school	1.84%	-	0	1
Primary school (1-4)	8.91%	-	0	1
Preparatory school (5-7)	0.78%	-	0	1
Secondary school (8-11)	0.19%	-	0	1
Superior education (>11 years)	0.00%	-	0	1
Farm Characteristics (n=310)				
Total lowland area owned	0.88	0.63	0.10	4.00
Number of plots owned	2.74	1.35	1.00	10.00
Total rice area planted	0.68	0.55	0.00	3.00
Number of plots planted	2.27	1.37	0.00	10.00
Total rice area harvested	0.57	0.61	0.00	3.00
Production	422.41	503.90	0.00	3100.00
Yield	0.61	0.53	0.00	3.00

In terms of farm characteristics, the farm area owned per household is, on average, approximately one hectare and the number of plots is 2.74. The area and number of plots planted were less than the area and number of plots owned. Common reasons for non-planting all owned areas included intentionally leaving land fallow, and not planting due to sickness or death of the plot manager or some member of their family, such as a husband or children. The land harvested is also inferior to the one planted, as a result of pre-harvest losses. Yields averaged 0.61 tons per hectare, which is particularly low. The average yield (tons/ha) in the whole of the Sub Saharan Africa region between 2000 and 2007 was 1.67 (1.56 for Western Africa, 0.92 for Central Africa, 2.25 for Eastern Africa, and 1.07 for Southern Africa: Dawe, 2012). The main reason for such a low output during the year of this study was erratic rains during that crop season.

Table 2. Lowland Rice Production Systems and Rice Farmers Characteristics (cont.)

Rice Cultivation Methods (n=310)				
Tractor utilization	2.13%	-	0	1
Charrua utilisation	51.22%	-	0	1
Fertilizer utilisation	3.96%	-	0	1
Soil Quality				
Rich	23.89%	-	0	1
Rich on Average	72.93%	-	0	1
Poor	2.55%	-	0	1
Very Poor	0.64%	-	0	1
Tenure				
Lease	0.33%	-	0	1
Bought	0.33%	-	0	1
Donated	14.52%	-	0	1
Borrowed	4.29%	-	0	1
Inherited	80.53%	-	0	1
Percentage of lowland ownership	95.19%	-	0	1
Percentage of formal title	0.34%	-	0	1
Perceived risk of expropriation/removed in the next five years				
High	15.43%	-	0	1
Medium	26.69%	-	0	1
Low	57.88%	-	0	1

Mechanisation is very low for female lowland farmers with only two per cent having access to tractors to plough their land. “Charruas” (ploughs) drawn by cows are more widely used, with 51% of farmers reporting their use. The use of inputs apart from seeds is virtually inexistent, with merely 4% of farmers using fertilizer and none reporting having used herbicides or pesticides. In terms of soil quality, 24% and 73% of respondents consider their soil to be of Rich and Very Rich quality, while very few have the perception of poor or very poor soil quality. With respect to land tenure, most farmers have inherited their land or received it as a donation. Nearly all (95 per cent) report that they formally own their land, however virtually none have a land title. This is not reflected in farmers' perceptions of tenure security, as only 15% perceive a high risk of expropriation, and 27% perceive a medium risk of expropriation or land being removed during the next five years. This is an indicator that the majority of farmers' trust in customarily defined rights over land.

The main government institutions involved in the regional seed system are the Regional Directorate of Agriculture and the National Institute for Agricultural Research (INPA) Station of Contuboel (regional office of the national agricultural research institute). Despite its mandate to provide extension services, INPA's activities in Contuboel Research Centre are mainly focused on seed production, and extension services are residual and are dependent on donors' support. A few NGOs, such as Guiarroz, and large farmers associations, such as APALCOFE, represent the sole institutions that provide more consistent technical assistance to farmers beyond seed donations. Table 3 below shows that only half of the farmers have contact with agricultural organizations, 38% of farmers report receiving assistance from Guiarroz, 15% from Inpa Contuboel and 12% from APALCOFE.

Table 3. Contact with Agricultural Organisations (n=310)

Variable	Mean	Std. Dev.	Min	Max
Contact with any Agricultural Organisation	50.8%	0.50	0	1
Contact with Inpa Contuboel	15.2%	0.36	0	1
Contact with Guiarroz NGO	37.7%	0.49	0	1
Contact with Apalcofe Association	12.3%	0.33	0	1

As in the case of many poor countries with underdeveloped seed systems, the great majority of farmers obtain their seed from their own seed stock which is saved from the previous year's harvest. This is particularly evident in Contuboel, were 93% of lowland rice farmers use their own seed for planting (see Table 4). Following the use of their own seed, the most-used sources are social networks: *Family, Neighbour, or a Friend from the village* (2%) and *from outside the village* (2%). Other sources, such as *Seed Banks, the National Agricultural Research Institute (Inpa-Contuboel Research Center),* and *Agro-multipliers* were residual. *Local Markets and NGOs* did not supply seed for rice farmers in the 2014 rainy season.

Table 4. Seed Sources by cultivated plot rainy season 2014 (n=744 plots)

	Freq.	Per cent	Cum.
Own seed	693	93.15%	93.15%
Agromultipliers	5	0.67%	93.82%
Seed Banks outside the village	3	0.40%	94.22%
Seed Banks in the village	11	1.48%	95.70%
Family, Neighbour, or a Friend outside the village	13	1.75%	97.45%
Family, Neighbour, or a Friend from the village	13	1.75%	99.19%
Inpa-Contuboel	6	0.81%	100.00%
Local Market	0	0	100.00%
NGOs	0	0	100.00%

Of the sampled farmers, only 25% reported possessing the necessary economic resources to buy seed in case of not having saved enough seed in 2014: 16% were members of seed banks, and only 17% declared having seed saved for the following rainy season in 2015.

Table 5. Seed sources by farmer for the next rainy season 2015 (n=310 Farmers)

	Freq.	Per cent	Cum.
Own	54	16.88%	16.88%
Agromultipliers	26	8.13%	25.00%
Seed Banks outside the village	23	7.19%	32.19%
Seed Banks in the village	9	2.81%	35.00%
Family, Neighbour, or a Friend outside the village	102	31.88%	66.88%
Family, Neighbour, or a Friend from the village	77	24.06%	90.94%
Inpa-Contuboel	17	5.31%	96.25%
Local Market	5	1.56%	97.81%
NGO	7	2.19%	100.00%

While farmers possessed their own seed saved up for the 2014 rainy season, their lack of stored seed for the 2015 season meant that they were planning on using other sources for seeds. The main source of seed anticipated for the following season was social networks, with 32% of farmers reporting they would resort to a *Family, Neighbour, or a Friend outside the village* and 24% planning to source from a *Family, Neighbour or a Friend in the same village*. After own seed saved to plant the following year (17%), *Agro-multipliers*[12] ranks 4th in farmers' preferences, with 8% reporting them as main source of seed for the 2015 rainy season. Agro-multipliers are farmers who specialise in seed production, whose objective is to supply seeds directly to farmers and other agricultural organisations. However, in the

[12] Farmers who were trained to produce to produce quality grain seeds

interviews carried out with the agro-multipliers association, members reported that if farmers are in desperate need, seeds are typically supplied as a gift. This is true, not only for farmers known within their social network, but also for unknown farmers. *Seed banks within the village and seed banks outside the village* ranks 5th and 6th on farmers' preferred sources: 3% and 7%, respectively. It is worth noting that the fact that most of the alternative sources are outside the village indicates that farmers have the perception of covariate risk. That is to say, any shock that is likely to cause them a seed shortage will likely also affect other farmers from the same village, and therefore outside assistance is the only way to insure against such risks. Local markets, such as Agro-dealers and Inpa-Contuboel are the two sources which are considered to belong to the formal seed system, and they are among the least frequent sources that farmers turn to for sourcing seed, which reflects the reality that the formal seed system still only plays a minor role in the supply of the seed system as a whole. Finally, it is worth pointing out that from the interviews and focus group discussions, the issue was raised regarding whether the market for lowland varieties is virtually inexistent, unlike the varieties planted by men in the upland agro-ecological system. Therefore these results suggest that women looking for seeds in the markets are probably making use of upland rice varieties that perform well under the lowland agro-ecological system (e.g., Bani Malu, which is a variety that was frequently mentioned as being well adapted to both systems and which is particularly suitable *in situ*ations when the rainy season is delayed, as it is a short-cycle variety).

The main reason why farmers lacked saved seeds to plant the following year is due to delays in the rains, which means that production levels were low. Effective rains in most areas only started very late in the year and were insufficient for high levels of production during the remainder of the rainy season. In line with Contuboel sector data from this chapter's survey, the FAO[13] recently reported that at the national level, aggregate cereal production in 2015 was estimated to have increased by 28 per cent, in comparison to the 2014 rainy season harvest – which was the year on which this survey reports. In particular, rice (paddy) is the most important staple in Guinea Bissau, which also increased in production by 28 per cent in 2015, compared to the 2014 output - which was below the average. The FAO country brief also states that low production in 2014, combined with low producers' prices for cashew nuts (the main cash crop production in Guinea Bissau), led to a deterioration of food security across the country. Conforming with FAO's country data, the reasons cited for not having seed for 2015 (Table 6) are the following: *Harvest partial loss* (77%), followed by *Production not enough to secure both food and seed needs* (67%) and *More area to plant next year* (31%). The less frequently cited reasons included Total harvest loss, which affected 7% of the farmers. From the semi-structured

[13] http://www.fao.org/giews/countrybrief/country.jsp?code=GNB

interviews held with farmers, the main reason for partial and total harvest loss was the failure of seeds to grow after germination, due to irregular rains.

Table 6. Reasons for not having enough seed following rainy season (n=310 Farmers)

	Mean	Std. Dev.	Min	Max
Production was not enough to secure food and seed needs	67.19%	0.47	0	1
Harvest partial loss	77.34%	0.42	0	1
Harvest total loss	7.12%	0.50	0	1
More area to plant next year	30.86%	0.46	0	1
First Time planting	0.00%	0.00	0	0
Other reasons	0.00%	0.00	0	0

According to the World Food Program[14] (WFP) in Guinea Bissau, as of July 2015, the Food Security and Nutrition Monitoring System data showed that, overall, 11 % of households in Guinea-Bissau were food-insecure. However, this figure varies across regions: in some areas, up to 51 per cent of families are affected. The WFP PRRO 200526 Program (2013-2016) identified highly food insecure areas as a result of the WFP Comprehensive Food Security and Vulnerability Assessment which was carried out in 2010. Vulnerable populations were found in the Biombo, Quinara, Cacheu, Gabu, Bafatá, and Oio regions. The WFP[15] also reports that cereal production decreased in these areas. The main reported reasons for this reduced production include: asset destruction, lack of seeds and fertilizers, and rice field deterioration or destruction. Many of these problems arise from poverty, unemployment, and other social and economic problems. All of these causes and outcomes were aggravated by the delayed rains, which caused food security and nutritional problems among the most vulnerable population. The Sahel and West Africa – Harmonized Framework for June/August 2015 Map presented in **Appendix I** reports the food security situation in the country two months after the survey in this paper was carried out. This map shows that all northern regions of Guinea Bissau are under pressure with respect to food security, including Bafatá. The findings corroborate the findings from my survey that low levels of production of cereals in general, and rice in particular, contributed to food insecurity across the northern regions in Guinea Bissau.

This section has provided the context of the study area, the data collection methods, and on farmers and agriculture production characteristics. The following Section 3 provides the methodology employed in construction of the Seed Security Index. It should be noted that Section 4 provides more

[14] https://www.wfp.org/countries/guinea-bissau
[15] https://www.wfp.org/countries/guinea-bissau/overview

comprehensive information on seed security, by presenting descriptive statistics for the final set of indicators used to construct the Seed Security Index.

3. Methodology for the Construction of the Seed Security Index

In order to construct the new composite measure of seed security, I followed the general methodology proposed by the Joint Research Centre-European Commission (JRC-EC, 2008). Table 7 presents the steps for constructing a composite indicator, starting with the theoretical framework setting and ending with the analyses of the links of the constructed index to other variables of interest. The following subsections present a detailed description of the methods employed for each step.

Table 7. Steps for the construction of composite indicators

Theoretical framework – A theoretical framework should be developed to provide the basis for the selection and combination of single indicators into a meaningful composite indicator, under a fitness-for-purpose principle.

Selection of variables – Indicators should be selected on the basis of their analytical soundness, measurability, country coverage, relevance to the phenomenon being measured and relationship to each other. The use of proxy variables should be considered when data are scarce.

Multivariate analysis – An exploratory analysis (e.g., Cronbach Alpha, Principal Component Analysis) should investigate the overall structure of the indicators, assess the suitability of the data set, and explain the methodological choices, e.g., weighting, aggregation.

Imputation of missing data – Consideration should be given to different approaches for imputing missing values. Extreme values should be scrutinised, as they can become unintended benchmarks.

Normalisation – Indicators should be normalised to render them comparable.

Weighting and aggregation – Indicators should be aggregated and weighted according to the underlying theoretical framework.

Robustness and sensitivity – An analysis should be undertaken to assess the robustness of the composite indicator in terms of, for example, the mechanism for including or excluding single indicators, the normalisation scheme, the imputation of missing data, and the choice of weights.

Links to other variables – Attempts should be made to correlate the composite indicator with other published indicators as well, in order to identify linkages through regressions.

Visualisation – Composite indicators can be visualised or presented in a number of different ways, which can influence their interpretation. Regarding the real data – composite indicators should be transparent and should be able to be decomposed into their underlying indicators or values.

Source: adapted from JRC-EC (2008)

3.1. Selection of Variables

FAO's (2015) report on "Seed Security Concepts and Indicators" is the most recent attempt to standardise seed security indicators - suggesting a number of indicators to measure each of the dimensions that contribute to farmer's seed security. While the FAO approach is very comprehensive, there are some issues within the proposed set of indicators that merit some discussion, in order to contextualise the final selection of variables for the construction of the index. This discussion has the objective of highlighting the difficulty with which many of these indicators can be quantified, and addresses some of their conceptual weaknesses. Although, at the time of the design of the survey, this report was not yet available, however the rich set of variables collected by the survey enabled the proposed indicators to be computed. Accoringly, the discussion below serves to guide the final choice of indicators to be used in the multivariate analysis in this chapter (**Table 9. Index Variables Final Set**).

Table 8. Dimensions and Indicators of Seed Security

Dimensions	Indicators
Seed Availability (seed supply at the right time and place)	• **Quantity of own saved seed stored at the household;** • Quantity of seed known to exist within social networks; • Quantity of grain of preferred varieties and crops available in local markets at planting time which farmers could use as seed; • Quantity of seed available with seed companies and local seed stockists at planting time; • Quantity of seed available through seed aid organisations at planting time; • Prices of seed in local markets, seed companies and local seed stockists; • **Proximity of seed sources in relation to the household – e.g., distance to local markets, local seed stockists.**
Seed Access (means to acquire)	• Amount of seed accessible to the household through social networks (social access); • **Level of household income obtained through different sources;** • **Wealth of household, as defined by fungible assets (e.g., livestock);** • Purchasing power of households (disposable income relative to price of seed in local markets).
Seed Quality (germination, physical purity, free from pests and diseases)	• Proportion of diseased seeds from different seed channels (on-farm; local market; social network) • Rate of germination of seeds from different seed channels: provided by farmers, local market, social network • Mean % physical purity of seeds from different seed channels: provided by farmers, local market, social network

	• Mean % varietal purity (when a pure variety has specific advantages) of seeds from different seed channels: provided by farmers, local market, social network
Varietal Suitability (adapted crop varieties farmers prefer and need)	• **Level of farmers' satisfaction with the crop and varieties they are currently growing, or desire to grow;** • Specifically desired characteristics which are/are not present in the varieties which they are currently growing; • Number and types of problems related to current varieties (duration, pest, disease, yield); • Farmer's access to accurate and useful information about varieties they are being supplied with.
Resilience (stability of seed system in the context of shocks and stresses)	• **Livelihood diversity (risk spreading);** • Crop diversity (risk spreading); • **Different abilities to switch between seed source channels – linked to: amounts of stored seed, degree of social access, proximity to local markets;** • **Different levels of asset ownership and ability to liquidate assets;** • **Different access to information about climate, seed sources, prices;** • Different policy environments (e.g., whether the informal sector is recognised as a *bona fide* source of seed or not in the existing policy frameworks).

Source: FAO (2015)

The indicators formatted in bold are the indicators that are used in this analysis. Those not in bold have not been used in this study, for the following theoretical and technical reasons: (i) The indicator is not applicable in a context of state fragility with a virtually absent seed formal sector; (ii) the level of analysis of the indicator is irrelevant to the scope of this study, which is to identify seed security at the household and/or farmer level; (iii) the indicator is conceptually challenging, and; iv) technical difficulties were experienced in collecting the data for the indicator.

Those that were ruled out because they were not relevant to the context (i) are those that are not suitable, as in the lowland agro-ecological production system there are no local markets, neither private seed companies, nor any stockists.

The indicators ruled out under Category (ii) are more suited to a spatial/geographical analysis, such as those referring to quantities available from different sources in an aggregated fashion. [16] Those ruled out under Category (iii) raise conceptual and measurement concerns, such as *Quantity of seed known*

[16] Quantity of grain of preferred varieties and crops available in local markets at planting time which farmers could use as seed; Quantity of seed available with seed companies and local seed stockists at planting time; Quantity of seed available through seed aid organisations at planting time; Prices of seed in local markets, seed companies and local seed stockists

to exist within social networks and *Amount of seed accessible by the household through social networks*. A social network is not something finite, in the sense that there is an *a priori* number of sources that are time invariant, to which a farmer can always resort to in case of need. In practice, the size of these networks mostly depends on the farmers' required quantity and the availability from social network members. Social networks typically develop in a step by step process, based on a combination of social and geographic distances. One of the findings from the semi-structured interviews and focus groups was that a farmer starts to contact the nearest social link, then the second nearest social link, and so on, until the quantity of seed needed is met. Furthermore, even if one assumes that a farmer has a fixed number of social members to ask for seed, it is very difficult for him to know what amount of seed is available among network members. In terms of measurement challenges, those indicators related to social networks which are represented in different dimensions all appear to be measured by the same variable, which is phrased in slightly different ways, e. g. quantity of seed available within a farmer's social network. The indicator *Different abilities to switch between seed source channels – which is linked to: amounts of stored seed, degree of social access, and proximity to local markets (henceforth the "switching" indicator)* is also extremely difficult to quantify. Part of the problem is that it is not very clear what this indicator is intended to measure, and it can be interpreted as being a farmer's ability to switch between sources and the extent to which farmers have simultaneous access to different sources at any time, in addition to the ability to choose the source with the lowest costs - which conflates in one indicator's dimensions of both availability and access, and makes any quantification difficult. Fourthly, the Seed Quality indicators, even if measured at the community level[17], cannot feasibly measure germination, diseased seeds, physical purity, or varietal purity, as these assessments require technical expertise, in particular equipment that is not currently available at the regional agricultural research centre[18] or at the national level. Finally, although most of the Varietal Suitability variables are suited for the household context and are feasible to collect, the FAO (2015) report that first suggests them was only published after the survey was carried out, and was not available as an input when the survey was being designed. Instead, the survey drew on the available literature at the time, which focused on quality, whereby the utilisation/quality dimension was defined as being the quality that farmers find acceptable, considering both variety and seed quality (Sperling & McGuire, 2012). Accordingly, recognising farmers to be key actors in assessing quality needs for both seed quality and the desired varieties, the variable included to reflect this dimension captured farmers' perceptions with respect to this utilisation dimension, which conflates both seed quality and varietal suitability.

[17] As this would be extremely onerous at the household level
[18] There used to be a seed laboratory at INPA Contuboel research station, but it is no longer active

Overall, 9 indicators were selected or adapted out of 27 of the FAO's proposed indicators. These 9 indicators are the best suited for measuring the 5 dimensions of seed security in a conceptually and technically rigorous way, given the literature available and the advancement of seed security concept at the time of the survey's design.

Following the above discussion on the FAO's Seed Security Indicators Framework and the literature review covered in the introduction where the theoretical framework is presented, **Table 9. Index Variables Final Set** presents the variables selected within the dataset to construct the Seed Security Index. These variables represent the different dimensions of seed security and they include a select sub-set of the FAO-proposed indicators discussed above, as well as additional new variables which were proposed in order to better capture the dimensions of seed security at household level. The variables disaggregated by gender, which are highlighted in bold in **Table 9***,* are those that differ between the Ungendered and Engendered Seed Security variables sets used in the Multivariate Analysis performed in Sub-section 4.2 following the methods presented in Sub-section 3.2. As explained in the Introduction, the gendered and ungendered disaggregation is pertinent, given the fact that the vast majority of farmers are women (see Table 1), and consequently only household level indicators are disaggregated where there is variation by sex, as the other indicators are engendered "by design".

Table 9. Index Variables Final Set

Variables	**Description**	**Type of Variable (units)**
Dimension 1: Seed Availability		
Seed available in the quantity needed in 2014 †	Reported having seeds available in the quantity they needed and at the right time for planting in 2014	Dummy Variable (Yes=1; No=0)
Quantity of available seed per capita 2014	Quantity of total available seed from all sources per capita in 2014	Continuous (kilograms per capita)
Distance to the main seed source area	Distance to Contuboel village	Continuous (kilometres)
Dimension 2: Seed Access		
Household Contacts with seed providing organizations	Number of seed providing organizations (NGO's, Associations,	Discrete Ordinal

	Government, etc.) with which farmers are currently connected	
Membership of Agricultural Association (U) **Female Membership of Agricultural Association (E)**	At least one member of the household belongs to an Agricultural Association At least one female member of the household belongs Female Membership of Agricultural Association	Dummy Variable (Yes=1; No=0)
Household agricultural income (U) **Female agricultural income (E)**	Household Total Agriculture Income Agriculture Income received and managed by women	Continuous (FCFA/Year)
Household non agriculture income (U) **Female non agriculture income (E)**	Total household income accruing from non-agricultural activities (commerce, handicraft, salary etc.) Income accruing from non-agricultural activities (commerce, handicraft, salary etc.) received and managed by women	Continuous (FCFA/Year)
Household livestock value (U) **Female owned livestock value (E)**	Sum of the market value of the livestock owned by men and women Sum of the market value of the livestock owned by women	Continuous (FCFA)
Dimension 3: Seed Quality		
Crop losses caused by pest and/or disease ˥	Reported crop losses caused by pest and/or disease, in previous season	Dummy Variable (Yes=1; No=0)
Dimension 4: Varietal Suitability (and Quality)		
Farmer satisfaction with the quality of seed and varieties currently growing	Reported satisfaction with the quality and varieties they are currently growing	Dummy Variable (Yes=1; No=0)
Dimension 5: Stability of seed system in the context of shocks and stresses (resilience)		
Household Income diversity (U)	Number of income sources	Discrete Ordinal
Female Income diversity (E)	Number of income sources owned and managed by woman	Discrete Ordinal

Wealth of household as defined by durable goods	Number of durable goods owned	Discrete Ordinal
Links to information providing organizations	Number of information providing organisations (NGO's, Associations, Government, etc.) with which farmers are currently connected	Discrete Ordinal
Varietal Diversity	Number of different varieties planted	Discrete Ordinal

Legend: U- Ungendered variable; E- Engendered variable; Ɨ variables proposed in addition to FAO's selected variables

Given that **seed availability** refers to the farmers' supply of seed from all sources, the indicators selected and adapted from the FAO's framework were the following: i) Quantity of own saved seed stored at the household, and ii) Proximity of seed sources in relation to the household. As the quantity of own seed in absolute terms has the undesired property of being a function of the household size and land ownership, the variable used instead is *total available seed per capita in 2014*. The option of not using the absolute value of seed used, as suggested in FAO's indicators, results from the fact that seed use is related to family size. Therefore instead of having a seed security measure, the indicator would ultimalty reflect houselhold consumption driven demand for lowland rice with implications in later use of the index[19]. In addition to these two variables, I have also included a dummy variable which took the value of 1 for farmers reporting having seeds available in the quantity they needed and at the right time for planting in 2014. On the whole, this dimension is represented by three variables.

With respect to the **seed access** dimension, as this refers to the "ability to acquire seed through exchange, loan, barter, or social networks" (FAO, 2013), the variables chosen to construct the index are: i) *contacts with seed providing organisations*; ii) *agriculture income; iii) non-agriculture income*, and; iv) *livestock value*. With respect to the dimension of **varietal suitability**, farmers were asked whether they were satisfied with the seed quality and varieties that they were currently growing. As already pointed out above, by the time the questionnaire was designed there only three dimensions where quality was a conflation of both varietal suitability and quality of seeds, and to this end the question included to cover varietal suitability also includes farmers' perception of the quality of seed.

[19] If any of the indices employed in Chapter 3 analysis were constructed with the absolute value of seed used, results on determinants of seed security could be interpreted as factors of rice (seed) production. Also, results on the effect of seed security on food production would rather reflect the effect of seed as an input to food production.

In order to capture more specific information on quality in a disaggregated fashion from varietal suitability, an additional **seed quality** variable was constructed. Seed quality is a complex dimension in itself, and it can be measured through different attributes, e.g.: i) physical (e.g., not damaged, free of weeds and matter, uniform seed size); ii) physiological (germination and vigour); iii) genetic (e.g., adapted to local conditions, pest and disease tolerance), and; iv) health (presence or absence of disease-causing organisms) (FAO, 2007). An exhaustive review of specific seed quality attributes was out of the scope of this survey, and there are several technical limitations to collecting this type of data in a household survey context. Instead, *Crop losses caused by pest and/or disease* is used as a proxy for seed quality, which is believed to at least partially capture this dimension. The genetic attributes of seed quality are reflected by the adaptation to local conditions and also vulnerability to pests and disease (FAO, 2007). Therefore, the fact that this variable captures past occurrences of pests and disease means that it will reflect at least one attribute of seed quality.

Resilience in the context of the shocks and stresses dimension at the household/farmer level is integrated into the index through the number of income sources, wealth of the household as defined by durable goods, and the number of household links to information-providing organisations. Given that all households in the region operate under the same policy environment, in this analysis, the FAO's proposed indicator of "Different policy environments" is not relevant. Varietal diversity is also included as a resilience variable, given its instrumental role in risk spreading.

The majority of variables included in the analysis are in line with FAO'S framework and recommended set of indicators, with the exception of those that were deemed irrelevant to the current analysis, or were problematic, as explained above. Descriptive statistics for the final set of variables selected to construct the index are presented in Sub-section 4.1.

3.2. Multivariate Analysis

Some exploratory methods can be carried out to investigate the overall structure of the indicators, with the objective of assessing the suitability of the data set and preparing the ground for the empirical approach to weighting and aggregating the indicators for the Seed Security Index.

In principle, we want the data to identify what the appropriate structure of the index should be, and how it identifies different groups of people with different sources of seed insecurity. Principal Component Analysis, Factor Analysis and Cronbach Coefficient Alpha are all examples of methods which do precisely this. Each of these multivariate analyses has its strengths and weaknesses, which are outlined below (JRECEC, 2008). The structure in the data is explored by applying two of these methods, focusing on the individual indicators dimension of the data. Two types of Principal

Component Analysis are employed: standard Principal Component Analysis and Polychoric Principal Component Analysis.

Principal Components Analysis

Among the many multivariate techniques available to construct composite indicators, the most widely used is principal component analysis (PCA). This technique of dimensionality reduction was created by Pearson (1901) and further developed by Hotelling (1933). Working from an initial set of correlated variables, PCA generates uncorrelated components where each component is a linear weighted combination of the initial variables. For instance, let us suppose there are Q variables $x_1, x_2, \dots x_q$ $(i = 1,2 \dots, Q)$ and yet most of data variation can be obtained by a smaller number of say P variables $Z_1, Z_2 \dots, Z_P$, the principal components of which are uncorrelated ($j = 1,2 \dots, p$)

$$Z_1 = a_{11}\ x_1 + a_{12}\ x_2 + \ldots + a_{1q}\ x_q$$

$$Z_2 = a_{21}\ x_1 + a_{22}\ x_2 + \ldots + a_{2q}\ x_q$$

$$\ldots$$

$$Z_p = a_{p1}\ x_1 + a_{q2}\ x_2 + \ldots + a_{pq}\ x_q$$

In the above equations there are as many principal components as there are variables, and therefore the next step is to choose which P<Q principal components preserve the "lion's share" of the cumulative variance of the original data. The weights a_{ji} for each principal component, which are also called component or factor loadings, are provided by the eigenvectors of the correlation matrix (or if the original data is standardised, by the co-variance matrix) from which it is possible to say the following about the data: 1) the absence of correlation, which indicates that the principal components are measuring different dimensions in the data. This correlation property is highlighted by the fact that they are orthogonal to one another, which means that the indices are measuring different independent dimensions of the phenomenon of interest in the data; 2) the first principal component accounts for the largest proportion of the variance of the original data, the second principal component accounts for the maximum of the remaining variance, and so on, where the last of the principal components absorbs all the remaining variance not accounted for by the preceding components.

$$a_{i1}{}^2 + a_{i2}{}^2 + \ldots + a_{iQ}{}^2 = 1,\ i = 1,2, \dots, Q$$

PCA involves finding the eigenvalues λ_j , $j = 1, \dots, Q$ of the sample covariance matrix CM

$$\text{CM}= \begin{bmatrix} cm_{11} & cm_{12} \dots & cm_{1Q} \\ cm_{21} & cm_{22} \dots & cm_{2Q} \\ \dots & & \\ cm_{Q1} & cm_{Q2} \dots & cm_{QQ} \end{bmatrix}$$

Where cm_{ij} is the covariance of variables x_i and x_j and the diagonal element cm_{ii} is the variance of x_i . The eigenvalues of the Matrix are the variances of the principal components and can be obtained by solving the following equation:

$$|CM - \lambda I| = 0$$

where I is the identity matrix, and λ the vector of eigenvalues. There are as many eigenvalues as there are Q and, due to independence, and their sum is equal to the sum of the variances of the original indicators.

$$\lambda_1 + \lambda_2 + \cdots + \lambda_Q = cm_{11} + cm_{22} + \cdots + cm_{QQ}, i = 1,2, \dots, Q$$

It is common to standardise the variables to mean 0 and variance 1, in order to prevent one variable having an over-influence on the principal components.

Principal Component Analysis with Polychoric Correlations

PCA was originally developed for multivariate normal data and is best used with continuous data. A widely known empirical application of PCA to compute Socio-economic Status Composite indicator was developed by Filmer and Pritchett (2001) as a solution to solving the problem of measuring wealth, when consumption and income data are unavailable or not very reliable. However, Kolenikov and Angeles (2004) point out that the discrete nature of the data often used to construct these types of indexes raises statistical problems. These problems have been highlighted by many authors in the social measurement literature, namely Olsson (1979), Bollen and Barb (1981), Johnson and Creech (1983) and DiStefano (2002) (as cited in Kolenikov & Angeles, 2004). One of the main issues is that the discrete data violates distributional assumptions in methods where continuous variables are assumed or expected - such as PCA. For instance, discrete data tends to have high skewness and kurtosis, especially if the majority of the data points are concentrated in a single category, and thus it does not satisfy the assumption of normal distribution. When dealing with continuous data, PCA is an appropriate method, however when some of the variables are discrete, alternative methods should be used.

Kolenikov and Angeles (2004) suggest using PCA with polychoric correlations as an alternative method, as it deals with the problems raised by discrete data and has the advantage that the proportion of explained variance is more accurate than that generated by PCA. Polychoric correlation can be seen as a Pearson's correlation for ordinal variables $X \: and \: Y$. When calculating polychoric correlation between two ordinal variables, it is assumed that these variables are a result of categorising two other latent variables - $x \: and \: y$, which have a standard univariate normal distribution, and for which the joint distribution of these unobserved variables follow a standard bivariate normal distribution with correlation ρ (Olsson, 1979). The estimation of this correlation is the polychoric correlation. Once the polychoric correlations among pairwise of variables are obtained, the correlation matrix is constructed, and PCA is then performed in the same way as presented above.

Many of the indicators of seed insecurity in **Table 9. Index Variables Final Se*t*** are discrete measures. Therefore, in order to explore the structure of the data and to generate weights for the variables, while taking into account the discrete nature of some of the variables, principal component analysis (PCA) using polychoric correlations was employed to construct the index (Kolenikov & Angeles, 2004). In this way, a comparison with the simple PCA can indicate whether the weights and seed security index is sensitive to the discrete nature of the data. The approach taken here follows Kolenikov and Angeles (2009), who compute principal components from the matrix of polychoric correlations between the variables. Their application involved Demographic and Health Survey data from Bangladesh, and their purpose was to explain the differences between different PCA procedures. This approach has also been widely applied in other studies, for example in the construction of an asset index in Ecuador (Moser & Felton, 2006), for a multi-country social institutions and gender index (Branisa et al., 2009), in an early childhood health index in Colombia (Osorio et al., 2013), and also for a poverty index in Cameroon (Njong & Ningaye, 2008). Most of the literature on the construction of food security indexes (e.g., Demeke et al., 2011; Wineman, 2016; Beegle et al., 2017) employs PCA procedures to compute the weights, however, they do not deal with discrete data issues.

However, one of the possible draw backs of PCA with polychoric correlations is that the estimated matrix of correlations is not guaranteed to be semi-positive definite. Therefore, in order to estimate the component loadings, the matrix is forced to replace negative eigenvalues with zeroes and as a consequence distorted correlations and non-existent multicollinearity among the variables are introduced, resulting in larger loadings (Njong & Ningaye, 2008). As higher loadings are pointed out to be the main benefit of PCA with polychoric correlations when compared to other PCA methods (e.g., Kolenikov & Angeles 2004, 2009), constraining the matrix in this way could mean that the advantages of polychoric PCA are overstated. However, if the resulting correlation matrix is not positively definite, then its non-positive entries are solely due to sampling fluctuations and are usually small. Accordingly, as our interest is in principal components with the largest eigenvalue(s), the fluctuations in the smaller ones are not a concern (Gerbing & Anderson, 1987; Kolenikov & Angeles, 2004; Njong & Ningaye, 2008).

3.3. Normalisation, Weighting, and Aggregation

To avoid adding up apples and oranges, **normalisation** is required before the indicators are aggregated, as these have usually been calculated by using different units of measurement. These indicators need to be expressed in similar units, in order to be able to compare them and to perform mathematical operations on them. There are two main methods that are more generally applicable: i) Standardisation - converting the indicators to a common scale by subtracting a mean value for the indicator and dividing by the standard deviation, and ii) Min-Max - converting the indicators to a common scale by subtracting a minimum value and dividing this by the difference between the maximum and minimum value for the indicator. In this study, among the various normalisation techniques available (Freudenberg, 2003), the standard deviation approach is used. This method is the most commonly used, due to its desirable characteristics for aggregation, as it converts all variables to a common scale and assumes a "normal" distribution. Additionally, it has an average of zero, which avoids aggregation distortions stemming from differences in variable means.

After extracting the principal components, the intermediate indicators for each of the principal components *j* retained, are calculated as follows:

$$ISSI_{ji} = \sum_{k=1}^{k-1} w_{kj} V_{kj} \qquad (1)$$

where $ISSI_{ji}$ is the intermediate indicator corresponding to an intermediate seed security indicator for component j, household i, and w_{kj} represents the weight of variable k in the component j, and V_{kj} is the normalised variable k in household i .

The weight of the variable k in the component j is obtained as follows:

$$w_{kj} = \frac{(a_{kj})^2}{eigenvalue_j} \qquad (2)$$

a_{kj} is the value of the factor loading of variable k in the principal component j, and $eigenvalue_j$ is the eigenvalue of the j^{th}principal component.

The Seed Security Index was then computed as a weighted aggregation of the intermediate seed security indicators, using the following formula:

$$SSI_i = \sum_{j=1}^{j-3} \alpha_j \, ISSI_{ji} \qquad (3)$$

Where SSI_i is the Seed Security Index for household i, and α_j is the weight of each of the principal components as a proportion of the variance explained by that component:

$$\alpha_j = \frac{eigenvalue_j}{\sum_{j=1}^{j=3} eigenvalue_j}$$

The PCA with polychoric estimation follows the same procedure, except it is estimated as a weighted average of the retained components, taking into account the proportion of explained variance by each dimension. The weightings were calculated by dividing each eigenvalue into the sum of the eigenvalues retained.

A numerical example for component 1 (Z_1) of the Ungendered Index is presented below to illustrate the main two equations of the aggregation method. The intermediate indicator for component 1 (Z_1) was computed as presented below[20]:

$$ISSI_{1i} = 0.041 * SAQN_i + 0.133 * QOWSP_i + 0.032 * QOSP_i + 0.041 * SS_i + 0.041 * SSN_i + 0.141 * \mathrm{HCSPO}_i$$

The method for weighting *Seed Available in the quantity needed in 2014 (SAQN),* is presented below:

$w_{SAQN\_C1} = \frac{(0.26)^2}{0.20} = 0.01$ which was then scaled to unit $\frac{0.01}{0.33} = 0.040$

Whereas the component 1 weight was computed as follows $\alpha_1 = \frac{0.20}{0.67} = 0.30$.

These two steps were repeated for each component and each intermediate indicator was aggregated as presented in Equation 3 above.

3.4. Robustness and Sensitivity

Following the JRC-EC (2008) steps for index construction (see Method 3), I used sensitivity analysis to assess the robustness of the Seed Security Index, by including and excluding individual indicators (see 4.2) and using different weighting schemes (see 4.4).

This section has described the methods employed for the Seed Security Index construction. Phenomena such as development, progress, poverty, social inequality, provision of infrastructure, etc., must all be measured as the 'combination' of different dimensions, and should be considered

[20] Seed Available in the quantity needed in 2014 (SAQN); quantity of own seed planted in 2014 (QOWSP); quantity of other sources planted in 2014 (QOSP); source of Seeds (SS); eed Social Network (SSN); household contacts within seed providing organisations (HCSPO).

together as a proxy for the phenomenon (Mazziotta & Pareto, 2013; De Muro et al., 2011). The same argument applies to seed security phenomena. The individual indicators and sub-indexes offer informative value which captures specific dimensions, however, the combination of the different dimensions of seed security, such as availability, access, quality, varietal suitability and resilience all serve as a proxy for seed security.

The next section shows the results by providing a seed system analysis which examines the different individual indicators used in the seed security index for the different dimensions. It then presents the multivariate analysis, whose purpose is not only to devise the weights to construct the index, but also to be informative about the structure of the data. The section will end with an investigation of differences in socioeconomic variables across seed security groups.

4. Results

4.1. Index Variables

Before moving to the Multivariate Analysis and the Index Weights, this section presents a seed security analysis, beginning with an assessment of the individual indicators for each dimension of the index. With respect to **seed availability**, Table 10 below shows that approximately 90% of farmers reported having seed in the quantity needed in the last rainy season.

Table 10. Dimension 1: Seed Availability

	Mean	Std. Dev.	Min.	Max.
Seed available in the quantity needed in 2014	0.90	0.30	0.00	1.00
Quantity of available seed per capita 2014	4.30	2.81	.62	21.28
Distance to the main seed source area	30.69	10.38	4.00	51.00

The average amount of seed per capita available to households in 2015 is 4.30kg. The average distance to the nearest village of Contuboel is 30 km, which is an area where most of the irrigated production systems are located and where agro-multipliers and INPA's regional research centre are to be found, and this is therefore an area of availability.

The **Access variables** shown below show that 45% of the households are in contact with seed-providing organisations, and that 80% of households have at least one member belonging to an agricultural organisation.

Table 11. Dimension 2: Seed Access

	Mean	Std. Dev.	Min.	Max.
Household Contacts with seed-providing organizations	0.45	0.80	0.00	4.00
Membership of Agricultural Association	0.80	0.40	0.00	1.00
Female Membership of Agricultural Association	0.70	0.46	0.00	1.00
Household agricultural income	356 944.50	356 448.30	0.00	3 266 000.00

Female agricultural income	35 864.68	40 618.32	0.00	350 000.00
Household non-agriculture income	211 117.70	628 007.20	0.00	8 400 000.00
Female non-agriculture income	2 219.36	23 679.84	0.00	400 000.00
Household livestock value	1 533 624.00	3 919 393.00	0.00	50 600 000.00
Female-owned livestock value	604 894.30	1 804 057.00	0.00	25 200 000.00

The gender-specific incomes and asset holdings are consistently lower on average than overall household values, which is to be expected. This will affect the magnitude of the access variables in the engendered index when compared to the ungendered ones. For instance, when the indicator is gender specific, this variable drops slightly to 70%. In terms of agricultural income, at the household level, mean income is 356 945 FCFA (600 USD), whereas female owned and managed income is on average 35 865 FCFA (60 USD) - one-tenth of a household's average income, which reflects the residual involvement of women in cash crop production for the household as a whole. The main reason for this dramatic difference between men and women, which is implicit in these numbers, is the fact that the two most profitable agricultural activities - cashew nut and livestock, are dominated by men. Non-agricultural income follows the same pattern. Household total non-agricultural income is on average 211 117 FCFA (354 USD), while female non-agricultural income is only 2 219 FCFA (4 USD). Interestingly, on the other hand, a livestock gender gap is not so evident, where total household livestock value is 1 533 624 FCFA (2578 USD), from which female owned livestock value represents approximately 40% of the total livestock of the household (604 894 FCFA/1.017 USD). It is worth pointing out that these results are particularly relevant, as the household structure is fairly well balanced in terms of the average number of female and male adults, with values of 3.1 and 2.9, respectively.

Table 12. Dimension 3 and 4: Seed Quality and Varietal Suitability

	Mean	Std. Dev.	Min.	Max.
Previous harvest affected by pest or disease	0.34	0.47	0.00	1.00
Farmer satisfaction with the quality and the varieties currently growing	0.63	0.48	0.00	1.00

Seed quality was measured by the occurrence of pests or disease affecting the previous harvest. Table 12 shows that slightly more than one-third of farmers reported that their previous harvest was affected by pest or disease. The fact that nearly two-thirds of farmers' seeds were resistant to pest and diseases is relatively high, which suggests a high genetic quality of these local seeds which are well adapted to local environmental conditions. Farmers' perceptions regarding **seed quality and varietal suitability** are in line with this result, with 63% of farmers reporting satisfaction with the rice seed quality and the varieties being currently grown.

Finally, four indicators capture the **resilience** dimension. Livelihood diversity was measured by the number of income sources of all household members. This indicator at the household level is approximately 4, whereas when disaggregated by female income sources, it drops to 0.78, reflecting that men have more diverse income generating activities than women. With respect to levels of asset ownership measured by the number of durable assets owned by household members, the value is 2.22. Access to sources of information regarding climate, seed sources, and prices is measured by contact with information-providing organisations, which is approximately 1 per household. The number of rice varieties grown by farmers in the lowland ranges from 1 to 5, with an average of 1.64 varieties of lowland rice grown per household.

Table 13. Dimension 5: Stability of the seed system in the context of shocks and stresses (resilience)

	Mean	Std. Dev.	Min.	Max.
Livelihood diversity	4.02	1.75	0.00	8.00
Female livelihood diversity	0.78	0.53	0.00	3.00
Wealth of household as defined by durable goods	2.22	1.32	0.00	8.00
Links to information providing organisations	1.10	1.37	0.00	4.00
Varietal Diversity	1.64	0.82	1.00	5.00

4.2. Multivariate Analysis

This sub-section describes the results of the different methods presented in Section 3.2 - Multivariate Analysis. The method and the set of indicators presented here are a result of the sensitivity analysis carried out in **Appendix IV**. The results of this analysis show that the gendered set of variables performed better, as the variance explained was consistently higher for the majority of variable sets and it performed particularly well with PCA with polychoric correlations, where with just 4 components, 73% of the variance in the data is explained. The analysis also shows that the best performing set of variables resulted from the initial set proposed in the previous section, without *Female Non Agricultural Income, Livestock Value, and Seed Quality.* These variables have very low correlation with other variables, and the PCA results for both methods revealed that the index will have more explanatory value if these are removed.

The multivariate analysis objective is twofold. First, it reveals the internal structure of the data in a way that best explains the variance, while providing valuable information about seed security in the specific context of Contuboel, as it captures the essence of the relationship among the various indicators of seed security. Secondly, it provides the weight for each variable computed from the highest loadings in each component. Notwithstanding the fact that weights are internally generated from the data, the index construction follows the theoretical underpinnings of seed security and therefore they are not context-specific in this sense. **Table 14** highlights in bold the higher loadings for each variable, which are those used to compute the weights in the following Section 4.3.

Table 14 shows the extent to which the principle components from the household survey data fit with the selected variables for seed security. We now discuss the relationship between loadings of the seed security and the principle components, whilst interpreting what these components represent.

Table 14. Principal Components Loadings with PCA with Polychoric Correlations

Variables[a]	Z_1	Z_2	Z_3	Z_4
Availability				
Seed available in the quantity needed in 2014	**-0.34**	0.29	0.17	0.33
Quantity of own seed per capita 2014	0.16	**0.48**	-0.20	0.13
Distance to main seed source area	**0.39**	-0.07	-0.16	0.02
Access				
Household Contacts with seed providing organisations	0.11	**0.57**	0.07	-0.08
Membership of Agricultural Association	**0.53**	0.01	0.08	0.10
Female agriculture income	-0.07	0.04	**0.69**	0.06
Varietal Suitability				
Farmer satisfaction with the seed quality and varieties currently growing	-0.30	**0.51**	-0.04	-0.10
Resilience				

Female livelihood diversity	0.14	-0.08	**0.63**	-0.08
Wealth of household as defined by durable goods	0.01	-0.03	-0.01	**0.87**
Links to information providing organizations	**0.44**	0.30	0.10	-0.16
Variety Diversity	**0.32**	0.03	0.01	0.25
Expl.Var	**0.23**	**0.22**	**0.15**	**0.10**
Expl.Var/Total Expl (α_j)	**0.33**	**0.32**	**0.21**	**0.14**

[a] Values in bold show in which factor (Z_1, Z_2, Z_3, and Z_4) the indicator reaches the highest loadings

The loading scores of Component 1 ($\boldsymbol{Z_1}$) capture what I call a **Biodiversity and Social Capital** type of seed security, which represents the specific variables of the availability, access, and resilience dimensions of seed security, through using the following variables: *Seed available in the quantity needed in 2014, Distance to main seed source market, Membership of Agricultural Association* and *Links to information providing organisations and Variety Diversity*. This component reflects a type of seed security where farmers have high levels of social capital in terms of associative engagement and contacts with development organisations providing information, and yet at the same time, they manage a more diverse varietal portfolio. However they are more distant from the main seed source centre of Contuboel Village, and this seems to implicate a cost in terms of the availability of the quantity needed at the time of planting. This component unravels the trade-offs between general social embeddedness/varietal diversity versus availability measures, such as having the desired quantities at the time of planting and geographical access to a place of high availability. It is also worth pointing out that perception over quality and varietal suitability is highly charged in this component, although less so than the second component, but with a negative score. This reflects that farmers that score higher under this component will be likely to have a lower perception of quality and varietal suitability. On the other hand, **Component 2 ($\boldsymbol{Z_2}$)** captures seed security in terms of **Availability, Social Access, and Utilisation** (Quality and Varietal suitability), as aspects such as *Quantity of own seed per capita 2014, Household Contacts with seed providing organisations* and *Farmer satisfaction with the varieties currently growing,* all have the highest loadings in this component. Furthemore, with smaller weights when compared to Component 1, *Seed available in the quantity needed in 2014* and *Links to information providing organisations* both have relatively large loadings. *Membership of Agricultural Association, Female agriculture income, Female livelihood diversity and Wealth of household as defined by durable goods and Variety diversity* all have negligible weights in this component. This will translate into a score where these variables have a residual expression, unlike Component 1, which has higher weights across all variables. Under this component the variable of *Distance to the main seed source* is negatively correlated with the other variables, as is expected, according to the theoretical definition of seed security. The analysis of the loadings of Component 1 and Component 2 show that these two components capture two complementary types of seed security, since by construction they are uncorrelated.

The interpretation of the two last components is more straightforward. **Component 3 (Z_3)** captures the **Short Run Wealth** of the household with high loadings for *Female Agricultural income* and *Female livelihood diversity*. Finally, **Component 4 (Z_4)** reflects **Long Run Wealth**, by capturing *Wealth of household as defined by durable goods*. This component has the lowest explained variance.

4.3. Index Construction Weights

The multivariate statistical method used to generate the weights for the variables is principal component analysis (PCA) with polychoric correlations. The interpretation of the weights is quite straightforward: each of them can be thought of as the variable's relative contribution to the overall Seed Security Index (SSI).

Table 15. Index Weights per Variable

Variables (k)	Principal Comp.	Weights (w_{kj})	$w_{kj} * \alpha_j$	Weights Scaled to Unit
Availability				
Seed available in the quantity needed in 2014	Z1	0.045	0.015	3%
Quantity of own seed per capita 2014	Z2	0.092	0.029	7%
Distance to main seed source market	Z1	0.059	0.019	5%
Access				
Household Contacts with seed providing organisations	Z2	0.133	0.043	10%
Female Membership of Agricultural Association	Z1	0.113	0.037	9%
Female agriculture income	Z3	0.290	0.062	15%
Varietal Suitability (and Quality)				
Farmer satisfaction with the seed quality and varieties currently growing	Z2	0.105	0.033	8%
Resilience				
Female livelihood diversity	Z3	0.244	0.052	12%
Wealth of household as defined by durable goods	Z4	0.691	0.097	23%
Links to information providing organisations	Z1	0.076	0.025	6%
Varietal Diversity	Z1	0.042	0.014	3%
		1.89	**0.43**	**1.00**

Within the **Availability** dimension variables, *Quantity of own seed per capita 2014* presents the highest loading, with a contribution of 7%. Within **Access**, *Female Household agriculture income* has the highest weight, with 15%, followed by *Household Contacts with seed providing organisations*, which contributes with 10%. **Seed quality and varietal suitability** has a weight of 8%. Among the **Resilience** variables, *Wealth of household as defined by durable goods* has the highest contribution to the index, with 23%. Overall, the variables with the highest loadings are *Wealth of household as defined by* *durable, Female agricultural income* and *Household Contacts with seed providing organisations.* Conversely, *Seed available in the quantity needed in 2014 and Varietal Diversity* are the variables with lower loadings.

The variables with the highest loadings are endowment related. This has to do with the fact that these three variables are captured by just two components, and that despite explaining a smaller proportion of variance, the variables they capture are highly loaded in these components, resulting in higher weights, unlike the majority of the other non-wealth related varieties which are concentrated within the first two components. The fact that the third and fourth components capture such a small number of variables is an indication of how these capture the sub-dimensions of seed security, such as access and resilience from an economic perspective, which are less correlated with the others, such as availability, social access, quality, and varietal suitability. Notwithstanding the fact that, in theory, those farmers that have more access as a result of a greater and diverse income are more resilient from an economic perspective and are more seed secure, however the "isolation" of variables capturing these sub-dimensions with respect to the others needs to be more seed specific, which suggests that this is not the case, such as in the specific context of Contuboel. As having more income, or being more resilient only translates into improved access and ultimately seed security, there is a more mature seed market, which is not the case.

Therefore, the key outcomes of multivariate analysis are the following:

- Construction of a theoretical Seed Security Index, which identifies seed security farmers from a theoretical point of view, where all variables contribute positively to the score (except distance), irrespective of the particular seed security dynamics which can be experienced in a particular context;
- Computation of two context-specific Seed Security Indices. The first and second principal components are linear indices of all the variables, and are not correlated between them. This property makes each index capture unique information on seed security sub-concepts, which represent complementary types of seed security. The first component captures **Biodiversity and Social Capital** seed security type, while the second component captures **Availability, Social Access, and Utilisation** – the non-endowment related seed security variables.

This approach is the most appropriate for two reasons. On one hand, an aggregate index based on normalised and summed indicators of seed security is useful for identifying hotspots where multiple aspects of seed (in) security occur simultaneously following the theoretical underpinning of the seed security framework. On the other hand, using the two first principal components as alternative indices, with the higher variance explained (65%)[21] is useful, as it reveals important information regarding the relations between the original variables, which are obscured in the aggregated index. Notwithstanding the important advance of the seed security framework in providing analytical concepts by which we can analyse seed systems, its use needs to be context-specific (Sperling & Cooper, 2003). Therefore, the following analysis will be conducted, using both the aggregated index and the first two principal component scores.

4.4. Village Ranking

One of the practical applications of seed security indices is that it enables the ranking of different regions, areas, or households in terms of the severity of seed insecurity. To illustrate this ranking exercise, the average of the SSI, and the alternative indices based on the two first principal components scores were computed for each village, which is locally called "Tabanca". The SSI ranges from -0.01 (Min) to 0.19 (Max), with lower values indicating greater seed insecurity and higher values indicating greater seed security. The Biodiversity and Social capital index ranges between -2.7 and 3.39 and the Availability, Social Access, Quality, and Varietal Suitability Index ranges between -2.30 and 2.67. To make the scales of the three indices comparable and to be able to compute them into a radar graph, a min-max normalisation was conducted.

[21] n.b. this is the explained variance of the two principal components over the total variance of the four retained components (See table 15 Expl.Var/Total Expl (α_j))

Figure 1. Seed Security Indices Radar Graph

Using the aggregated **Seed Security Index**, **Figure 1** shows that the most seed-insecure villages which are more likely to have very low levels of seed security simultaneously across all variables are: Sare Dembel, Sintchã Sulai, Talico, and Cancubanje Maunde. Conversely, Fajonquito, Fanca, Manato Fula and Bonco villages all have higher scores on every variable, on average.

From a **Biodiversity and Social Capital** seed security perspective, the villages of Sintchã Sulai, Madina Bobo, Talico, and Sintchã Mansata are the ones more likely to have lower levels of varietal diversity, as well as of associative membership and connections with development organisations, although being nearer to Contuboel, which is the the main source of availability in the Sector, they have higher levels of availability in terms of the quantity needed at the time of planting. Conversely, Sintchã Dicori, Sintchã Samba Tedi, Manato Fula, and Bonco villages, although they are more distant from Contuboel, they tend to have higher varietal diversity and social capital, albeit with a cost to availability.

Finally, the index capturing **Availability, Social Access, Quality, and Varietal Suitability** ranks worse for the Sintchã Dicori, Sintchã Samba Tedi, Farim Bali, and Jambur villages. Sintchã Samba, Sintchã Bambe, Talico, and Madina Bobo are the villages that perform best in terms of availability, social access, quality, and varietal suitability. These villages are likely to have farmers with higher levels of availability of seeds in terms of quantity per capita, and, in terms of reporting, they have sufficient quantity at the right time for planting, and are closer to a geographical area with consistent availability. Furthermore, these are villages which, on average, tend to have a more positive perception regarding seed quality and varietal suitability and greater access from a social perspective, as they have more connections with seed providing organisations.

Figure 1 also shows which villages perform badly under all Seed Security measures, such as Sare Dembel and Cancubanje Maunde, whereas Bonco is the only villages that has high levels of seed security across all indices.

These three different profiles of seed security captured by each of these indices should translate into different policy prescriptions. These aspects will be discussed in detail in the following Section 5 - Conclusions and Discussions. The next section explores how these different types of seed security vary in terms of household and farmers characteristics, respectively.

4.5. Descriptive analysis

Another practical application of the seed security index is to understand household socio-economic, geographic, or other characteristics associated with greater or less seed security. This can help policy and decision makers better understand which farmers may be at risk of insecurity and help expedite the identification and targeting of support to vulnerable farmers. To demonstrate this application, for each of the indices I have classified the sample households into two seed security groups - high and low, using the mean of the index as a decision point. Households that have positive index values are categorised in the relatively high seed security group (factor score ≥0: N=145), whereas those with negative index values are categorised as having a relatively low level of seed security (factor score <0: N=165).

In **Table 16**, I examine differences between these groups for a range of household and farm characteristics, in order to assess the use of the index for understanding household and farm characteristics which are associated with seed security, in such a way that confirms my hypotheses. For each of the indices, the differences between the more and less seed-secure groups for several demographic, economic, and institutional variables are provided in **Appendix V**, which are estimated by using a simple difference in means test against the null hypothesis of no differences. This table presents a summary of the characteristics of more secure farmers, in comparison with farmers with lower levels of seed security, for each of the three seed security measures based on the results presented in **Appendix V**.

Table 16. Differences in household characteristics by seed security groups

Characteristic	More Seed Secure w/ Seed Security Index	More Seed Secure w/ Biodiversity and Social Capital Index	More Seed Secure w/ Availability, Social Access, and Utilisation
Household characteristics			
Gender	Higher proportion of female-headed households ***	Smaller proportion of female-headed households***	Higher proportion of female-headed households
Age	Same	Older	Less age***
Family size	Larger family size***	Larger family size***	Smaller family size***
Education	Household head more educated	Household less educated ***	Household head more educated***
Ethnic Minority	Higher proportion of minority ethnic groups***	Higher proportion of minority ethnic groups***	Higher proportion of minority ethnic groups***
Long-run economic status	Higher levels of long-run economic status	Higher levels of long-run economic status	Higher levels of long-run economic status
Poverty Status[22]	Lower poverty incidence***	Lower poverty incidence***	Higher poverty incidence
Dependency ratio	More number of dependents	More number of dependents***	Less number of dependents***
Lowland farmers experience ratio	More experienced***	More experience***	Less experienced
Farm Characteristics			
Area Owned	More area***	More area***	More area***
Fragmentation	More fragmented***	More fragmented***	More fragmented***
Landless	Larger proportion of farmers not owing the land	Larger proportion of farmers not owing the land***	Lower proportion of farmers not owing the land***
Soil Quality	Lower proportion of rich soil	Lower proportion of rich soil***	Higher proportion of rich soil***
Risk of Expropriation	Higher proportion of farmers with low risk of expropriation***	Higher proportion of farmers with low risk of expropriation***	Lower proportion of farmers with low risk of expropriation***
Labour	More labour***	More labour***	More labour***
Farming Outcomes			
Production	More production***	More production***	More production***
Yield	Higher yield***	Lower yield***	Higher yield***

[22] Estimated by using a poverty STATA statistical package which computes a series of poverty measures based on income distribution

These exploratory results show that many characteristics associated with being more seed secure change according to the type of seed security being measured.

The seed secure farmer characteristics for both the aggregated **Seed security Index** and the **Biodiversity and Social Capital Index** are the same relatively. In terms of demographic differences, when compared to the less seed-secure households, the more seed-secure households are more likely to have larger household sizes, to belong to an ethnic minority, and have a higher dependency ratio. With respect to economic differences between the two groups, these results show that seed-secure farmers are more likely to have a higher socio-economic status and are less likely to be poor. In terms of farm characteristics, seed-secure farmers are more likely to own more land, cultivate more plots, with a larger proportion of farmers having a perception of low risk of expropriation. One difference between these two indices lies in the proportion of female-headed households – for with the Seed Security Index, more seed-secure farmers tend to have a female-headed household, while seed from Biodiversity and Social Capital Index farmers have a lower proportion of female-headed households. Furthermore, seed security is associated with lower soil quality for both indices, although the difference is only statistically significant for Biodiversity and Social Capital Index seed. Finally, although rice production is higher for seed-secure farmers for both measures, yield does not differ across the two groups under the first measure, while for the second index, yield is lower for seed-secure farmers using this measure.

The characteristics of seed-secure farmer computed with the **Availability, Social Access, and Utilisation Index** differ substantially from seed security as captured by the former indices. In terms of demographic characteristics, seed-secure farmers heads of households are younger and more educated, have smaller families, and a lower number of dependents. Regarding farm characteristics, they are less likely to be landless and to have richer soil, although a greater proportion of farmers tend to have the perception of a low risk of expropriation. The two variables reflecting economic status were not statistically significant across the two groups.

Common across the three types of seed security is the finding that seed secure farmers tend to own more land, have a larger number of plots, and to have more labour working for them.

To further explore the determinants of seed security, in Chapter 3 I provide more details on the literature covering determinants of seed security and estimate the determinants of each of these three types of seed security, using regression analysis.

5. Conclusions and Discussion

This chapter is designed to answer the three research questions that can shed some light on the complex phenomena of seed security.

The **first research** question of this chapter is “are the proposed set of indicators to measure the different dimensions of seed security valid as representatives of this phenomena”. The different statistical analyses carried out in this chapter showed that the majority of the initial set of indicators resulted in a reliable index—that is to say, combining them produced a robust benchmark to proxy seed security. This is reflected by high levels of correlation among the variables and the results of the multivariate analysis, which show us that with few components, we can capture much of the variance in the data. Furthermore, the findings indicate that engendering the index by including gender-specific, rather than non-gender specific variables resulted in a more reliable index, by better reflecting the intra-household gender dynamics and their role in seed security.

The **second research** question is “which dimensions and indicators of seed security have a more prominent role in explaining the phenomena of seed security”. From the multivariate analysis (Section 4.2), I found that the first two principal components that capture half of the variance (50%) in the data which reflect aspects of Biodiversity, Social Capital, Availability, Social Access, and Utilisation (quality and varietal suitability), are those that best explain seed security for lowland rice varieties in Guinea Bissau. However, when computing the individual weights (Section 4.3) which result from a combination of variables individual loadings and the respective component weight, this shows that other variables, despite being in components with less expression in terms of explained variance, become more salient as a result of their individual loading. Therefore, among the individual indicators, those with the strongest explanatory power were *Wealth of household as defined by durable goods, Female agriculture income, Female livelihood diversity* and *Household Contacts with seed providing organisations.* Conversely, *Seed available in the quantity needed in 2014, Distance to main seed source market* and *Varietal Diversity* were the variables with weaker contributions. On the whole, it is clear that farmers’ social and economic access to seeds, as well as resilience in terms of livelihood, are a reflex of seed security status. However, it is worth putting these results in the context of other dynamics of the seed system as a whole. In Section 2, it was shown that lowland farmers make very limited use of local markets for seeds, even in times of need when affected by a bad harvest. Therefore, this begs the question of what is the relative importance of economic-related aspects of access in seed security? Putting these results in a broader context, they suggest that being better off in terms of agricultural income and livelihood diversity, although being a reflex of more seed security by definition, it is of less significance, as it cannot be enjoyed, as the market for lowland seeds is virtually inexistent.

Therefore, and in line with the multivariate analysis, what really seems to reflects farmers' status with respect to seed security are the aspects related with variables captured by the two first components, which are highly charged with non-endowment related variables. Aspects such as biodiversity, social capital, availability, social access, and utilisation, are the seed security aspects that seem to play a more prominent role for seed security in the lowland agro-ecological system. Furthermore, the results suggest that there are two types of seed security that do not come together, in the sense that they reflect two complementary types of seed security. On one hand, the biodiverse, marginal environment and aid recipient type of farmer/area, and on the other hand, the farmer with unconstrained availability, less marginal environment, more socially-connected to specific seed organisations and with a greater perception of quality and varietal suitability. This does not mean that the income or asset related variables should be discarded, as they do indeed represent a form of seed security, even if this cannot be experienced at present, it can be seen as a "dormant" dimension waiting to be enjoyed and it is relevant from a policy perspective. However, having seed available and having social and geographical access to seeds, as well as varietal diversity is what is more important for seed security in this context.

These results are also useful for gaining a deeper understanding of the main issues affecting seed security in Guinea Bissau and are reflective of the challenging conditions that characterised the agricultural year during which the survey took place. As shown by the individual indicators in Section 4.1, **Availability** was not a key issue during the year of the survey for the majority of farmers, given that the previous year was a good harvest. Had the survey taken place during the following year, during the same period, the results would likely have been quite different, as the subsequent harvest (2015) was extremely poor and 55% of farmers reported that as a consequence, they would have to look to family and friends for seed sources (for details, see Section 2). In the Introduction, I defined three different categories of seed security: (i) *Seed-secure households* – which have sufficient resources at their disposal to grow and access seed, and to experiment with new varieties; (ii) *Crisis-prone households* – which may become seed-insecure in the case of stress events, such as droughts, and; (iii) *Chronically seed-insecure households* – which are less-endowed farmers continuously facing difficulties of accessing good quality seed (Longley et al., 2002). These results suggest that the index might be capturing chronic seed insecurity. The index does not capture crisis-prone households in lowland Guinea Bissau in 2014, as there was no crisis that year that would place households in that category. Instead, SSI scores households from the seed-secure category through to being chronically seed-insecure.

The **third research** question is “what are the household and farm characteristics associated with seed insecurity that can be used to increase the predictive power of vulnerability going forward and improve readiness for support”. The results have shown that seed-secure farmers relatively have the same characteristics for both the Seed Security Index and the Biodiversity and Social Capital Index. However, what is more revealing is that their differences, in particular with respect to variables such as soil quality, rice production, and yield. More seed-secure farmers, under the Biodiversity and Social Capital Index, have lower soil quality on average, and despite the higher production, the yield is 30% lower for seed-secure farmers. This points to two findings: (i) it provides further evidence of the type of farmers captured by this index - a marginal environment type of farmer with low soil quality and low yields, despite their diverse varietal portfolio, and; (ii) it further suggests that these farmers might be using diversity as a risk mitigation strategy, for they prefer to have a diverse portfolio that provides them with greater stability of production. However, this comes at a cost, as it impacts average yields negatively. This is in line with the research that finds the positive effect that varietal or crop diversity has on production stability (e.g., Di Falco & Chavas, 2008; Di Falco & Chavas 2009; Di Falco, Bezabih & Yesuf, 2010).

The empirical literature on seed security reports that disadvantaged groups, such as female-headed households and ethnic minorities, are among the most seed-insecure households in rural communities in developing countries (GTZ & CGN, 2000). However, my results across the three indices are not consistent with this pattern. Female-headed households are more predominant in seed secure farmers, as measured by the Seed Security Index and Availability, Social Access, and Utilization Index, although the difference is only statistically significant for the former. Only seed-secure farmers, as measured by the Biodiversity and Social Capital Index fit this characterisation. Being an ethnic minority does not seem to affect seed security. However, it is worth pointing out that this region is quite homogeneous in ethnic terms, as there are two predominant ethnic groups - Fulas and Mandingas, and there very few households (just three) in the sample that do not belong to these two groups. These households could be the ones that could more accurately be labelled as being a Minority. Overall, these results mean that, on average, Mandinga are more likely to be seed-secure than the other ethnic groups, across the three measures of seed security.

There is also a predominant view amongst academia that seed security is closely related to poverty, and that it is more prevalent among marginal and poor farmers (Cromwell, 1996; GTZ & CGN, 2000; Sperling et al, 2006; Almekinders, 2000). The first two indices are aligned with the literature in this respect, as there is greater poverty incidence among seed-insecure farmers for both measures. For all the indices, seed-insecure farmers have lower levels of long-run economic status, however, the differences are nor statistically significant.

Cromwell (1996) claims that seed-insecure farmers experience frequent drought, poor soil quality, weak infrastructure, and limited access to land and labour. The Availability, Social Access, and Utilisation Index provides a seed-insecurity farmer profile which is more aligned with this depiction. Seed-insecure farmers own less area, employ less labour, and are more likely to be landless and perceive soil to be of lower quality. The Seed Security Index captures a similar picture, although the difference between seed security status on soil quality is not statistically significant.

Finally, seed-secure farmers are more likely to have greater security of tenure, as they face lower risks of expropriation. Haugen (2001) and Sperling *et al* (2006) identify tenure insecurity as being an institutional determinant of seed insecurity. Results show that this is the case in the first two indices, where seed-insecure farmers are more likely to have higher perception of the risk of expropriation. The Availability, Social Access, and Utilisation seed-insecure farmers are more likely to perceive a low risk of expropriation, which is at odds with the empirical results cited in the literature. A possible explanation for this is that seed-secure farmers are located in more valuable agro-ecological areas, namely nearer Contuboel and the Geba River Basin, which might be perceived as being more prone to beeing taken over by governmental or traditional authorities.

It is worth pointing out that the analysis hereby presented is exploratory, with estimates based on descriptive statistics which need to be treated with caution. Chapter 3 estimates the determinants of seed security, which provides in a sounder manner the characteristics associated with seed (in) security for each of these measures and further discussion will be carried out.

The **policy implications of these results** are threefold, as a consequence of the three types of seed insecurity identified. The **Seed Security Index** can identify villages or households where there is a need to implement interventions which are targeted at seed market development since the more that seed-secure farmers under this measure become highly endowed, and therefore more likely to have the economic means to access seed in case of need. Irrespective of their advantageous status in terms of seed security, rice yields are very low in Guinea Bissau in General[23] and in this area in particular[24], therefore there is an effort than needs to be made in order to increase yields. An example of this type of initiative could be the support of agro-multipliers, the main regional seed producers placed in Contuboel and Bafatá irrigated areas, towards a more market-oriented approach through training, providing management tools, and support their linkages to village markets and commercial traders across the region to sell their produce, namely where there is a more dynamic economy and demand for seeds is likely to be higher. Through this approach farmers will have access to improved varieties

[23] See Section 3 – Chapter 3
[24] See Section 2 – Chapter 2

being produced by the agro-multipliers. Since there is also evidence that improved varieties perform particularly better than traditional, when combined with complementary inputs such as fertilizers (Bruce, Donkoh, & Ayamga, 2014, Johnson, Hazell, & Gulati, 2003; De Janvry & Sadoulet, 2002), better-off farmers are the most likely to adopt new technologies. It is worth pointing that despite the relative wealth of these farmers, the majority of farmers' communities in Guinea Bissau are affected by high levels of poverty, which is likely to curtail demand for seeds from the private sector. On the other hand, the consistent state of fragility together with low demand is likely to result in that the lowland production system be unattractive market to the private sector. Hence, in the short and medium term an effective way to move towards a more developed seed market will be to support agro-multipliers as the formal seed producers and construct a value chain, by linking them to local markest and commercial traders. Regarding interventions targeted at seed insecure farmers under this measure should have a holistic approach in terms of promoting seed security, as they score badly for all dimensions of seed security, ranging from availability to resilience. Improving seed security for chronically seed-insecure farmers might be more effective if it concentrated on improving availability at the farm level, and on improving social and geographic access to seed-surplus areas, such as Contuboel. In terms of increasing availability, policies should be targeted at supporting lowland rice production, namely through increasing irrigation and the planting area, by promoting mechanisation and the use of sustainable fertilizers and high yielding varieties. With respect to social access, promoting network-based interventions[25] that encourage the social inclusion of marginalised farmers could be instrumental in improving social access, as well as in improving variety suitability and diversity among these farmers, both of which are also associated with low levels of social capital. Also seed fairs can be an example of intervention that can be effective in promoting social/economic access to quality and suitable seeds, and where farmers can exchange information on traits and farming practices, associated with particular seeds. Finally, addressing the geographic distance of these farmers to areas with seed availability requires integrating these concerns in the broader context of development projects aimed at improving transportation in rural areas, through building improved roads and providing affordable transportation. Also in line with social access, and as a way of curtailing the geographical distance issue, is for NGOs providing agricultural extension services to be more inclusive into providing seeds to seed-insecure areas i.e. bring the seed to the farmer. Improving economic access and resilience, which would ultimately deal with the geographical isolation problem, requires development-oriented interventions based on a holistic analysis of livelihood strategies to improve the income and wealth of farmers in general, and female lowland farmer, in particular. Finally, to solve issues related with low seed quality and less-preferred varieties, interventions should be

[25] Examples of such interventions in similar sectors see Kumbamu (2018) and Valente (2010)

favoured such as participatory plant breeding, participatory varietal selection, and targeted programmes to improve seed quality and promote access to varieties with more desired traits.

The **Biodiversity and Social Capital Index** can identify households or areas for intervention as follows. The most seed-secure farmers, although they are more likely to have a more diverse varietal portfolio and to be more socially embedded, it is they who tend to experience lower levels of availability and are more likely to farm in marginal environments, with lower soil quality, and with less seed quality and preferred varieties. These farmers possess the most appropriate profile for benefiting from participatory plant breeding and participatory varietal selection, as it is they who are seed-insecure in terms of availability, quality, and varietal suitability. To this end, the national research system institutions, especially INPA-Contuboel and other partner organisations could target these farmers to work towards increasing production, through the use of higher quality and more suitable varieties, in one hand. On the other hand, promote the integration of existing local varietal diversity portfolio and the associated traditional knowledge into the formal research system. Given their higher varietal diversity, these communities can also benefit from community level crop conservation interventions, to promote the existing *in situ* diversity conservation of locally preferred varieties, namely through gene banks and training farmers in the production of seed and planting material, in order to improve their access to quality seed and planting material of their traditional varieties. Conversely, seed-insecure farmers subject to this measure have low levels of diversity and social capital. These farmers experience a limited choice of varieties, with specific traits in the local system, and therefore expanding their access to a wider choice is critical to improve their diversity-related seed security issue. Promoting diversity management through *in situ* conservation, such as community seed banks or local gene banks, and the promotion of seed fairs linking farmers with greater varietal diversity to others who have a more limited portfolio is the type of intervention that could effectively support farmers to achieve greater diversity and consequently, to be more resilient.

Finally, seed insecurity, as measured by the **Availability, Social Access, and Utilisation Index**, can be overcome by a combination of the interventions suggested above. Underperformance for Availability and Social Access can be tackled through the same type of measures as those suggested under the aggregated index for these particular dimensions. While Utilization, in particular improving access to higher quality seed and access to novel varieties with preferred traits, can be improved through the same type of interventions as suggested in the case of seed-secure biodiverse farmers, who also suffer from the same utilisation problem.

Finally, due to the limitations of the data available, the variable set used to construct the seed security index could be richer, particularly with respect to variables representing Seed Quality and Varietal

Suitability dimensions. Future research should further refine the index to define a core set of variables which, ideally, are based on data which is commonly available across national and local contexts, in order to establish a common approach that can be widely applied. Furthermore, this approach should be applied to a larger sample, where it could be assessed in more diverse socio-economic and agro-ecological settings to further test its usefulness. Apart from addressing these limitations, future research should also extend the descriptive analysis carried out to further explore the determinants of seed security, using sophisticated econometric methods and investigate the effects of seed security on food production and food security.

Nonetheless, this chapter has demonstrated that multiple indicators of seed security can be reliably combined into a single index which reflects seed security. This offers a new and practical tool for measuring seed security across a range of contexts. This can offer policy and decision makers' easily-understandable data, which can be used to: (i) improve targeting efficiency and effectiveness of seed sector interventions at different levels, and (ii) be used as a tool to understand the household, farm, agro-ecological, and geographic characteristics associated with seed insecurity, in order to inform seed sector policies, interventions, and services. Additionally, it can also be used to test the efficacy of policies and services over time. Finally, it is worth pointing out that the Index is not only informative in its own right, but also that the statistical analysis that underlies its computation provides valuable information which can be used to assess the relative importance of dimensions and individual variables for seed security in a given context.

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Appendix I. Sahel and West Africa – Harmonised Framework for June/August 2015

Appendix II. Correlation Matrices

Ungendered Index. Principal Components with Ordinal Variables Correlation Matrix

	Seed available in the quantity needed in 2014	Quantity of available seed per capita 2014	Distance to main seed source area	Household Contacts with seed providing organizations	Membership of Agricultural Association (U)	Household agricultural income (U)	Household non agriculture income (U)	Household livestock value (U)	Crop losses caused by pest and/or disease†	Farmer satisfaction with the quality of seed and varieties currently growing	Household Income diversity (U)	Wealth of household as defined by durable goods	Links to information providing organizations	Varietal Diversity
Seed available in the quantity needed in 2014†	1.0													
Quantity of available seed per capita 2014	0.1	1.0												
Distance to main seed source area	- 0.1	- 0.0	1.0											
Household Contacts with seed providing organizations	0.2	0.5	0.0	1.0										
Membership of Agricultural Association (U)	- 0.1	0.0	0.5	0.2	1.0									
Household agricultural income (U)	0.1	- 0.0	- 0.0	- 0.1	- 0.0	1.0								
Household non agriculture income (U)	- 0.1	- 0.0	0.1	- 0.1	0.0	0.3	1.0							
Household livestock value (U)	0.1	0.0	- 0.1	- 0.0	- 0.1	0.5	0.0	1.0						
Crop losses caused by pest and/or disease†	0.0	0.1	0.1	0.1	- 0.0	0.1	- 0.0	0.1	1.0					
Farmer satisfaction with the quality of seed and varieties currently growing	0.2	0.3	- 0.2	0.4	- 0.3	- 0.0	- 0.2	0.0	0.3	1.0				
Household Income diversity (U)	- 0.1	- 0.1	0.0	- 0.2	0.3	0.4	0.4	0.2	- 0.1	- 0.5	1.0			
Wealth of household as defined by durable goods	0.1	0.0	0.0	0.0	0.0	0.2	0.3	0.3	- 0.0	- 0.0	0.1	1.0		
Links to information providing organizations	- 0.1	0.3	0.1	0.7	0.3	0.0	0.1	- 0.1	- 0.1	- 0.1	0.2	0.0	1.0	
Varietal Diversity	- 0.0	0.2	0.1	0.0	0.2	0.1	- 0.0	0.2	- 0.1	- 0.2	0.2	0.1	0.2	1.0

Ungendered Index. Principal Components with Polychoric Correlations Matrix

	Seed available in the quantity needed in 2014	Quantity of available seed per capita 2014	Distance to main seed source area	Household Contacts with seed providing organizations	Membership of Agricultural Association (U)	Household agricultural income (U)	Household non agriculture income (U)	Household livestock value (U)	Crop losses caused by pest and/or disease ↑	Farmer satisfaction with the quality of seed and varieties currently growing	Household Income diversity (U)	Wealth of household as defined by durable goods	Links to information providing organizations	Varietal Diversity
Seed available in the quantity needed in 2014 ↑	1.0													
Quantity of available seed per capita 2014	0.2	1.0												
Distance to main seed source area	-0.2	-0.0	1.0											
Household Contacts with seed providing organizations	0.5	0.5	0.0	1.0										
Membership of Agricultural Association (U)	-0.2	0.0	0.5	0.3	1.0									
Household agricultural income (U)	0.2	-0.0	-0.0	-0.1	-0.0	1.0								
Household non agriculture income (U)	-0.2	-0.0	0.1	-0.1	0.1	0.3	1.0							
Household livestock value (U)	0.3	0.0	-0.1	-0.0	-0.1	0.5	0.0	1.0						
Crop losses caused by pest and/or disease ↑	0.1	0.2	0.1	0.2	-0.1	0.1	-0.0	0.1	1.0					
Farmer satisfaction with the quality of seed and varieties currently growing	0.4	0.5	-0.3	0.8	-0.6	-0.0	-0.2	0.0	0.5	1.0				
Household Income diversity (U)	-0.2	-0.1	0.1	-0.2	0.4	0.4	0.4	0.1	-0.1	-0.6	1.0			
Wealth of household as defined by durable goods	0.1	0.1	0.0	0.0	0.1	0.2	0.3	0.3	-0.0	-0.1	0.2	1.0		
Links to information providing organizations	-0.2	0.3	0.1	0.8	0.6	0.0	0.1	-0.1	-0.1	-0.1	0.3	0.1	1.0	
Varietal Diversity	-0.1	0.3	0.1	0.1	0.4	0.1	-0.0	0.1	-0.1	-0.3	0.3	0.1	0.2	1.0

Engendered Index. Principal Components with Ordinal Variables Correlation Matrix

	Seed available in the quantity needed in 2014	Quantity of available seed per capita 2014	Distance to main seed source area	Household Contacts with seed providing organizations	Female Membership of Agricultural Association (E)	Female agricultural income (E)	Female non agriculture income (E)	Female owned livestock value (E)	Crop losses caused by pest and/or disease†	Farmer satisfaction with the quality of seed and varieties currently growing	Female Income diversity (E)	Wealth of household as defined by durable goods	Links to information providing organizations	Varietal Diversity
Seed available in the quantity needed in 2014	1.0													
Quantity of available seed per capita 2014	0.1	1.0												
Distance to main seed source area	- 0.1	0.0	1.0											
Household Contacts with seed providing organizations	0.2	0.5	0.0	1.0										
Female Membership of Agricultural Association (E)	- 0.1	0.1	0.4	0.2	1.0									
Female agricultural income (E)	0.1	0.1	0.1	0.2	0.2	1.0								
Female non agriculture income (E)	0.0	- 0.1	- 0.0	- 0.0	- 0.0	- 0.1	1.0							
Female owned livestock value (E)	0.1	- 0.0	- 0.1	- 0.1	- 0.1	0.1	0.2	1.0						
Crop losses caused by pest and/or disease†	0.0	0.1	0.1	0.1	- 0.1	0.2	0.1	0.1	1.0					
Farmer satisfaction with the quality of seed and varieties currently growing	0.2	0.3	- 0.2	0.4	- 0.3	0.1	- 0.0	- 0.0	0.3	1.0				
Female Income diversity (E)	- 0.0	- 0.0	0.1	0.1	0.3	0.5	0.3	0.0	0.0	- 0.2	1.0			
Wealth of household as defined by durable goods	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.2	- 0.0	- 0.0	0.0	1.0		
Links to information providing organizations	- 0.1	0.3	0.2	0.7	0.4	0.3	- 0.0	- 0.1	- 0.1	- 0.0	0.3	0.0	1.0	
Varietal Diversity	- 0.0	0.2	0.1	0.0	0.2	0.1	- 0.1	0.2	- 0.1	- 0.2	0.2	0.0	0.2	1.0

Gendered Index. Polychoric Correlations Matrix

	Seed available in the quantity needed in 2014↑	Quantity of available seed per capita 2014	Distance to main seed source area	Household Contacts with seed providing organizations	Female Membership of Agricultural Association (E)	Female agricultural income (E)	Female non agriculture income (E)	Female owned livestock value (E)	Crop losses caused by pest and/or disease↑	Farmer satisfaction with the quality of seed and varieties currently growing	Female Income diversity (E)	Wealth of household as defined by durable goods	Links to information providing organizations	Varietal Diversity
Seed available in the quantity needed in 2014↑	1.0													
Quantity of available seed per capita 2014	0.2	1.0												
Distance to main seed source area	-0.2	0.0	1.0											
Household Contacts with seed providing organizations	0.5	0.5	0.0	1.0										
Female Membership of Agricultural Association (E)	-0.2	0.1	0.5	0.3	1.0									
Female agricultural income (E)	0.2	0.1	0.1	0.3	0.2	1.0								
Female non agriculture income (E)	0.1	-0.1	-0.0	-0.0	-0.0	-0.1	1.0							
Female owned livestock value (E)	0.3	-0.0	-0.1	-0.2	-0.1	0.1	0.2	1.0						
Crop losses caused by pest and/or disease↑	0.1	0.2	0.1	0.2	-0.1	0.3	0.2	0.2	1.0					
Farmer satisfaction with the quality of seed and varieties currently growing	0.5	0.5	-0.3	0.8	-0.5	0.1	-0.0	-0.0	0.5	1.0				
Female Income diversity (E)	-0.1	0.0	0.1	0.2	0.5	0.6	0.3	0.0	0.0	-0.3	1.0			
Wealth of household as defined by durable goods	0.1	0.1	0.0	0.0	0.2	0.1	0.0	0.2	-0.0	-0.1	0.0	1.0		
Links to information providing organizations	-0.2	0.3	0.2	0.8	0.6	0.3	-0.0	-0.2	-0.1	-0.1	0.4	0.1	1.0	
Varietal Diversity	-0.1	0.2	0.1	0.1	0.4	0.1	-0.1	0.1	-0.1	-0.3	0.3	0.1	0.3	1.0

Appendix III. Eigen values and Cumulative Variance

Table 17. Principal Components with Polychoric Correlation: Engendered (Unrotated)

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	3.08	0.46	0.28	0.28
Comp2	2.63	1.41	0.24	0.52
Comp3	1.22	0.16	0.11	0.63
Comp4	1.06	0.11	0.10	0.73
Comp5	0.95	0.12	0.09	0.81
Comp6	0.83	0.19	0.08	0.89
Comp7	0.64	0.22	0.06	0.95
Comp8	0.42	0.09	0.04	0.98
Comp9	0.33	0.17	0.03	1.01
Comp10	0.15	0.44	0.01	1.03
Comp11	-0.29	.	-0.03	1.00

Table 18. Principal Components with Polychoric Correlation: Engendered (Rotated)

Component	Eigenvalue	Difference	Proportion	Cumulative
Z1	2.52	0.05	0.23	0.23
Z2	2.47	0.82	0.22	0.45
Z3	1.65	0.57	0.15	0.60
Z4	1.09	.	0.10	0.70

Appendix IV. Sensitivity Analysis

The use of gendered and ungendered sets of variables in the Multivariate analysis was conducted as a form of sensitivity analysis. The sensitivity analysis had three objectives: i) to understand which index, gendered or ungendered, is more consistent; ii) to select a final set of variables by excluding variables that have less explanatory value to the index, and; iii) to select the PCA procedure that performs better in order to subsequently compute the weights. As is typical in PCA, during the process of estimating the principle components, some of the indicators can contain very low levels of correlation with the other indicators. This constitutes a criterion for dropping these variables from the analysis. A preliminary analysis showed that this was indeed the case with *Non Agricultural Income* and *Livestock Value and Seed Quality.* Therefore, the estimations were undertaken without one or the other or both of these variables to test the relevance of the variable set to phenomenon being measured (see the correlation matrices presented in **Appendix II**).

Table 19. Comparative Analysis of Principal Components with Ordinal Variables vs Polychoric: Ungendered and Engendered

	PCA Variance Explained Eigenvalues>1	# Comp. Eigenvalues>1	Polychoric PCA Variance Explained Eigenvalues>1	# Comp. Eigenvalues>1
Ungendered				
No variables droped - Total Set	0.63	6	0.72	6
Non Agricultural Income, Seed Quality, Livestock Value	0.63	5	0.72	5
Non Agricultural Income, Seed Quality	**0.62**	**4**	**0.72**	**4**
Non Agricultural Income, Livestock Value	0.70	5	0.70	4
Livestock Value, Seed Quality	0.70	5	0.70	4
Non Agricultural Income	0.66	5	0.68	4
Seed Quality	0.67	5	0.75	5
Livestock Value	0.65	5	0.66	4
Engendered				
No variables dropped	0.63	6.00	0.80	6
Female Non Agricultural Income, Seed Quality, Female Livestock Value	**0.70**	**4**	**0.73**	**4**
Female Non Agricultural Income, Seed Quality	0.70	5	0.77	5

Female Non Agricultural Income, Livestock Value	0.70	5	0.77	5
Livestock Value, Seed Quality	0.70	5	0.76	5
Female Non Agricultural Income	0.64	5	0.74	5
Seed Quality	0.63	5	0.73	5
Livestock Value	0.63	5	0.80	5

The process of the exploratory analysis with principal components results in the determination of the number of factors to be retained - that is, which first Z_P components should be used to construct the index? There are a number of rules and criteria to ne used to select the number of principal components, namely: i) principal components with eigenvalues greater than one, and ii) principal components that account for at least 70% of total variation (JRC-EC, 2008). For this reason, four components were retained to compute the weights in the following section (for Eigen value and explained variance details, see **Appendix III**).

In the gendered sets of variables, the one that performs best is without the *Non Agricultural Income* and *Seed Quality* variables, as both methods have the highest variance explained with the smallest number of components, while for the gendered set of variables, this is the set that does not include *Female Non Agricultural Income, Seed Quality*, and *Female Livestock Value.* When comparing results between gendered and ungendered, **Table 19** shows that for the same set of indicators, under the conventional PCA approach, the gendered sets always perform better, except for the sets without single variables, whereas for the PCA with Polychoric correlation, the better performance of the gendered sets are consistently better across all variable sets, with the variance explained being always greater with equal or smaller number of components for the ungendered Index.

Finally, when comparing PCA with ordinal variables and PCA with polychoric correlations, the table shows that the latter performs better. When employed to the different variable sets, this method consistently explains a larger proportion of the variation for the same number of components, or less, when compared to PCA with Ordinal Variables. Additionally, this is a result of the higher correlation among variables for this method, as shown in **Appendix II**. However, the results in the tables presented in **Appendix III** confirm that PCA with Polychoric correlations has negative eigenvalues for components 12 and 13. However, this is not of concern, because, as pointed out in Section 3.2, it is only problematic when these non-positive entries are large in magnitude, which is not the case. Given the greater performance of the PCA with Polychoric correlations and the engendered variable set, the multivariate analysis was further developed to estimate the loadings, while removing the initial variables set from the indicators for Female Non-Agricultural Income, Seed Quality, and Female Livestock Value.

Appendix V. Mean differences between Seed Secure and Seed Insecure Households

Table 20. Differences in household characteristics by seed security groups: Seed Security Index

Characteristic	Description	Less secure	More secure	Stat. sig.[a]
Household characteristics				
Gender	Gender of household head (0 = male; 1 = female)	0.09	0.01	***
Age	Age of household head (years)	52.32	52.08	
Family size	Total family size (number)	13.01	15.14	***
Education	Education level of household head (years of schooling)	0.53	0.63	
Ethnic Minority	Ordinal variable ranging from Minority (1) to Majority (3) ethnic groups	1.13	1.46	***
Long-run economic status	Socio-economic status measured by Socio-Economic Status Index[26]	-0.11	0.11	n.d
Poverty Status[27]	Poverty Status (1=poor; non poor=0)	0.33	0.20	***
Dependency ratio	Members whose age is greater 65 and less 15 years on total household size	7.80	8.45	n.d
Lowland farmers experience ratio	Ratio between age and rice farming experience	0.45	0.73	***
Farm Characteritics				
Area Owned	Continuos Variable (hectares)	0.67	1.09	***
Fragmentation	Number of Plots Planted	1.95	2.87	***
Landless	Land Ownership Status (1 = Landless Farmer; 0=Farmers Owns Land)	0.11	0.17	n.d
Soil Quality	Soil quality dummy variable (0=poor or average, 1=rich)	0.27	0.21	n.d
Risk of Expropriation	Tenure security dummy variable measuring levels of risk of expropriation/land being removed(0=medium or high, 1=low)	0.51	0.65	***
Labour	Labor in person days for ploughing, planting, weeding and harvesting	466.26	684.45	***
Farming outcomes				
Production	Continuos Variable (kg)	314.14	581.63	***
Yield	Continuos Variable (kg/ha)	.61	.61	n.d

[a] Statistical significance of the mean difference between groups
*Significant at *p* = 0.1; **Significant at *p* = 0.05; ***Significant at *p* = 0.01

[26] Computed following Filmer and Pritchett's (2001) procedure
[27] Estimated with a poverty STATA statistical package, which computes a series of poverty measures based on income distribution

Table 21. Differences in household characteristics by seed security groups: Biodiversity and Social Capital Index

Characteristic	Description	Less secure	More secure	Stat. sig.[a]
Household characteristics				
Gender	Gender of household head (0 = male; 1 = female)	0.10	0.01	***
Age	Age of household head (years)	50.92	53.47	n.d
Family size	Total family size (number)	12.47	15.66	***
Education	Education level of household head (years of schooling)	0.73	0.43	***
Ethnic Minority	Ordinal variable ranging from Minority (1) to Majority (3) ethnic groups	1.08	1.51	***
Long-run economic status	Socio-economic status measured by Socio-Economic Status Index[28]	-0.08	0.08	n.d
Poverty Status[29]	Poverty Status (1=poor; non poor=0)	0.39	0.14	***
Dependency ratio	Members whose age is greater 65 and less 15 years on total household size	7.23	9.01	***
Lowland farmers experience ratio	Ratio between age and rice farming experience	0.34	0.83	***
Farm Characteritics				
Area Owned	Continuos Variable (hectares)	0.58	1.18	***
Fragmentation	Number of Plots Planted	1.97	2.85	***
Landless	Land Ownership Status (1 = Landless Farmer; 0=Farmers Owns Land)	0.06	0.21	***
Soil Quality	Soil quality dummy variable (0=poor or average, 1=rich)	0.33	0.15	***
Risk of Expropriation	Tenure security dummy variable measuring levels of risk of expropriation/land being removed(0=medium or high, 1=low)	0.47	0.69	***
Labour	Labor in person days for ploughing, planting, weeding and harvesting	529.91	619.39	***
Farming outcomes				
Production	Continuos Variable (kg)	345.64	548.40	***
Yield	Continuos Variable (kg/ha)	0.69	0.53	***

[a] Statistical significance of the mean difference between groups
*Significant at p = 0.1; **Significant at p = 0.05; ***Significant at p = 0.01

[28] Computed following Filmer and Pritchett's (2001) procedure
[29] Estimated with a poverty STATA statistical package that computes a series of poverty measures based on income distribution

Table 22. Differences in household characteristics by seed security groups: Availability, Social Acces, and Utilisation Index

Characteristic	Description	Less secure	More secure	Stat. sig.[a]
Household characteristics				
Gender	Gender of household head (0 = male; 1 = female)	0.03	0.07	n.d
Age	Age of household head (years)	54.46	49.95	***
Family size	Total family size (number)	14.82	13.32	***
Education	Education level of household head (years of schooling)	0.36	0.80	***
Ethnic Minority	Ordinal variable ranging from Minority (1) to Majority (3) ethnic groups	1.19	1.40	***
Long-run economic status	Socio-economic status measured by Socio-Economic Status Index[30]	-0.05	0.05	n.d
Poverty Status[31]	Poverty Status (1=poor; non poor=0)	0.24	0.29	n.d
Dependency ratio	Members whose age is greater 65 and less 15 years on total household size	9.14	7.10	***
Lowland farmers experience ratio	Ratio between age and rice farming experience	0.62	0.55	n.d
Farm Characteritics				
Area Owned	Continuous Variable (hectares)	0.78	0.97	***
Fragmentation	Number of Plots Planted	2.09	2.72	***
Landless	Land Ownership Status (1 = Landless Farmer; 0=Farmers Owns Land)	0.17	0.10	***
Soil Quality	Soil quality dummy variable (0=poor or average, 1=rich)	0.19	0.28	***
Risk of Expropriation	Tenure security dummy variable measuring levels of risk of expropriation/land being removed(0=medium or high, 1=low)	0.64	0.52	***
Labour	Labour in person days for ploughing, planting, weeding, and harvesting	446.59	702.72	***
Farming outcomes				
Production	Continuous Variable (kg)	236.74	657.29	***
Yield	Continuous Variable (kg/ha)	0.45	0.78	***

[a] Statistical significance of the mean difference between groups
*Significant at p = 0.1; **Significant at p = 0.05; ***Significant at p = 0.01

[30] Computed following Filmer and Pritchett's (2001) procedure
[31] Estimated with a poverty STATA statistical package that computes a series of poverty measures based on income distribution

Chapter 3. The effect of Seed Security on Food Production in Lowland Rice Farms in Guinea Bissau

This chapter builds on the findings of the previous chapter by employing the Seed Security Index and other seed security measures to estimate the determinants of seed security and its effect on food production.

List of Maps, Figures and Tables

1. Introduction

A well-developed agricultural sector depends on good seed. Seeds are at the core of farming activities and food production. Therefore, seed security is instrumental for food security (McGuire & Sperling, 2013, Dominguez, Gouveia, Cuna, Gasparini, & Hald, 2004; Kansiime & Mastenbroek, 2016; McGuire & Sperling, 2016) and for resilient livelihoods (FAO, 2003; Sperling & McGuire, 2016; Kansiime & Mastenbroek, 2016). Seeds are the most important input, and are frequently the only input used beyond labour and land (Dominguez et al., 2003; Louwaars & De Boef, 2012; Galié, 2013), particularly in marginal environments where the availability of and access to inputs is limited (Almekinders, 2000; McGuire, 2008).

Women have a critical role in maintaining both seed security and food security. Women's knowledge and expertise are, in many contexts, instrumental in the processes of saving, selecting, reproducing, storing, and sowing these seeds (Pionetti, 2005; Pionetti, 2006; Galié, 2013; Meinzen-Dick, Quisumbing, Behrman, Biermayr-Jenzano, Wilde, Noordeloos, & Beintema, 2011; Prain, 1992; Bellón, 1995; Sperling, Loevinsohn, & Ntabomvura, 1993; Padmanabhan, 2005). The World Bank Report on Gender and Agriculture (2009) reported that "Women are the main food producers in farm households, and so their seed security — in other words, their access to reliable supplies of good seed — is of the highest priority" (World Bank, FAO & IFAD, 2009; pp. 545). Underlying this statement is a clear recognition of the central role of women in ensuring food security for their families and also that seed security is a development priority for achieving this goal. In short, food security starts with seed security, and women have a pivotal role in maintaining seed security.

Both the definition and the dimensions of seed security were inspired to a great extent by the USAID's Food Security Framework, which reflects the underlying linkage between these two concepts. The 1996 World Food Summit adopted as a Food Security definition: ''Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life." (FAO, 1996). This definition was again refined in The State of Food Insecurity of 2001: "Food security [is] a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2002). This widely accepted definition entails the following dimensions: (i) Food Availability: addresses the "supply side" of food security and is determined by the level of food production, stock levels, and net trade; (ii) Food Access: an adequate supply of food at the national or international level does not in itself guarantee household-level food security. Concerns about insufficient food access have resulted in a greater policy focus on incomes, expenditure, markets, and prices in achieving food security objectives; (iii) Food Utilisation: is commonly understood to be the way the body makes the most of various nutrients in the food. Sufficient energy and nutrient intake by individuals is the result of good care and feeding practices, good food preparation, diversity of diet, and the intra-household distribution of food. Combined with good biological utilisation of consumed food, this determines the nutritional status of individuals; (iv) Food Stability: sustainability of the other three dimensions over time (McGuire & Sperling, 2011). Even if food intake is adequate for one day, a person might still be considered to be food insecure if they have inadequate access to food periodically, risking a deterioration of their nutritional status. Factors such as adverse weather conditions, political instability, or economic shocks such as unemployment, and rising food prices can have an impact on a person's food security status (FAO, 2008).

Regarding the definition of *seed* security, "Seed security exists when men and women within the household have sufficient access to quantities of available good quality seed and planting materials of preferred crop varieties at all times in both good and bad cropping seasons" (FAO 2015, p.2). There are five critical dimensions of seed security, which mirror food security, namely: (i) Seed availability; (ii) Seed access; (iii) Seed quality; (iv) Varietal suitability, and; (v) Resilience (FAO, 2015). (See previous Chapter 2 for more details.)

Despite the recognised importance of seed security to food production and security, relatively little empirical research exists regarding the relationship between seed security and food production and security outcomes (see the literature review in section 3). In particular, I found a substantial gap in the literature with respect to: (i) quantitative evidence of the determinants of seed (in)security, and; (ii) the causal relationship between seed security, food production, and food security and the mechanisms underlying this relationship. This chapter addresses this gap by studying the causal nature of this relationship and its underlying mechanisms.

This paper aims to answer three research questions: (i) What are the **determinants of seed security**? (ii) What are the **mechanisms underlying the relationship between seed, food production, and food security**? (iii) What is the **effect of two seed security measures**[32] **on food production**, and

[32] The complete Index developed in Chapter 2 and the Indices represented by the two principal components scores: (i) the first component score captures Biodiversity and Social Capital seed security type, and; (ii) the second component captures: Availability, Social Access and Utilisation, and the non-endowment related seed security variables.

consequently on food security? To answer these questions, I use survey data which I collected in the Bafatá Region of Guinea Bissau from February to March 2015, immediately after the harvest period. I collected socio-economic and agricultural data for a representative sample of 310 lowland female farmers in the Contuboel sector (the administrative unit which comes below regions). This sector was chosen as a case study, based on its direct relevance at the national level for rice production for household consumption (for details about the sampling strategy, see Chapter 1-Section 3).

The absence of temporal data constrains which possible empirical strategies can be used to **estimate the determinants of seed security**. In particular, it limits the use of other types of estimators (e.g., panel data estimators, or differences in differences), which could deal with different sources of endogeneity, namely time-invariant heterogeneity. Endogeneity can be a result of unobserved heterogeneity, namely of household, farm, and village-level characteristics which can affect both the outcome and some of the determinants, resulting in biased estimates. For example, villages' agro-ecological conditions might influence both cultivated area and seed security outcomes. As I'm interested in examining the individual relationships between different variables and seed security, I follow a parametric approach, whereby I estimate the determinants using three different estimators: Ordinary Least Squares (OLS); village-level Fixed Effects, and; village-level Random Effects. Causal interpretation must be taken with caution under this setting, however the large number of independent variables that are exogenous and the inclusion of a rich set of farm-specific variables (e.g., soil quality and distance to the household) as well as village-level characteristics (e.g., distance to main market and type of ecology) to deal with different sources of heterogeneity, address the potential for endogeneity bias, as far as possible.

To explore the **mechanisms underlying the links between seed security, food production, and food security,** I carried out a document analysis, using evidence from empirical research, reports, and field assessments from different areas, in order to shed some light on this intertwining relationship. As a result of the concern regarding endogeneity, the empirical challenge of **estimating the effect of seed security on food production** using observational studies rests with the ability to establish a suitable counterfactual, against which the impact can be measured. To accurately measure the effect of seed security on the food production of farm households, seed security would have to be randomly assigned, to ensure that influence of both observable and unobservable characteristics between seed-secure households, and those that are not, would be the same, whereby the estimated effect could have originated solely from the treatment – seed security. However, seed security cannot be randomly assigned and therefore the seed security status of a farmer is likely to be influenced by both observable and unobservable characteristics. This unobserved heterogeneity might lead to the endogenous treatment resulting in biased estimates. Approaches to deal with selection bias in cross-sectional data include: propensity score matching, generalised propensity score matching in a continuous treatment framework, and instrumental variable approaches. The fact that seed security is a continuous variable and that there is no valid instrument leaves the generalised propensity score matching as a feasible approach. Unlike the instrumental variables, the generalised propensity score approach does not deal with unobserved heterogeneity. However, given the rich choice of covariates, as well as the particular context of this research, I argue that identification is possible with a selection of observables approach. This stems from the fact that the female farmers' lowland community is relatively homogenous (e.g., regarding education level, religion, and ethnic group) which results in a greater homogeneity of unobserved variables. In addition, a household lowland farm is constituted of different plots, with each managed by an adult female in the household, who are usually wives of the head of the household, or the sons. Therefore, it can be argued that households have a "pool" of ability which results in the sum of the individual abilities of the spouses in the household, and that these can be considered to be random, with no significant differences across households. This same argument can apply to other possible unobserved variables, such as managerial skills. I therefore find that identification is a possibility under this particular context.

Results show that, not surprisingly, land, labour, and experience are the key determinants of all the seed security measures analysed, with a positive effect on seed security. Being a female head of household has a negative effect on both the Seed Security Index and the Biodiversity and the Social Capital Index, as expected. The determinants of the Availability, Social Access, and Utilisation Index are similar to the other indexes, with respect to labour, land, and experience, although female-headed households perform better than their male counterparts for this type of seed security. This study also found several mechanisms through which seed security affects food production, and consequently food security, and it describes these below in further detail. Finally, this chapter presents preliminary quantitative evidence to support the hypothesis of a positive effect of seed security on food production and ultimately food security, which suggests that causal pathways exist, through which this effect occurs'.

This chapter is organised as follows. Section 2 examines the literature on the links between seed security, food production, and food security. Section 3 provides the detailed context of seed security, food production, and food security in Guinea Bissau in general, and in the case study area in particular at the time and agricultural season covered by the survey. Section 4 presents the different methodologies for this study. Section 5 presents the quantitative results for the determinants of seed security and the effect of seed security on food production. Section 6 summarises the conclusions and points out some policy implications.

2. Links between Seed Security, Food Production, and Food Security

The literature on the determinants of seed security and on the links between seed security and food production and security is summarised below. The first subsection looks at which determinants of seed security are presented in the literature in order to identify gaps and inform the quantitative analysis carried out in Section 5.1. The second subsection provides a literature review on the links between seed security and food production and security to substantiate the causal relationship between seed security and food security by exploring the underlying mechanisms (Section 5.2). This review focuses on two strands of the literature to look for evidence of such mechanisms: 1) the economics literature focusing on food security and food production, and; 2) the agronomics literature covering seed systems, food production, and security.

2.1. Determinants of Seed Security

In the first part of this section, I present what I call the structural determinants of Seed Security, and in the second part the intermediary determinants. It is important to notice that the Seed Security dimensions and many of indicators proposed in FAO (2015) for each of these dimensions are what I have called intermediary determinants of seed security. The rationale for this terminology is that there is a pathway leading from the seed security structural determinants to the intermediary factors that determines uneven seed security outcomes, and ultimately food insecurity.

Structural determinants of Seed Security

Unlike food security, research on the qualitative determinants of seed (in) security is scarce, and quantitative evidence is virtually absent. Cromwell (1996) reports that chronic seed security is closely related with poverty, being more prevalent among marginal and poor farmers that experience frequent drought, poor soil quality, weak infrastructure and limited access to land and labour. Disadvantaged groups, such as women-headed households, landless households, refugees or displaced and ethnic minorities, are usually the poorest and the most seed-insecure in rural communities in developing countries (GTZ & CGN, 2000). Furthermore, poorer farmers are more prone to being caught in a vicious cycle of seed insecurity (Almekinders, 2000). Households suffering from chronic seed insecurity often tend to be the most affected by reduced access to seed following a crisis event (Longley, 1998; Longley, Dominguez, Saide, & Leonardo, 2002). Such households suffer from other forms of marginalisation, namely: i) economic - as seed insecure households are usually poor with little land or labour available; ii) ecological - as they usually live in areas prone to repeated drought and degraded soils; iii) political - as they might be located in unsafe areas (Sperling et al., 2006), and; iv) institutional - as marginal lands typically have uncertain tenure (Haugen, 2001; Sperling et al., 2006). Insecure tenure results in tenants having to cultivate different areas every year as they move from one marginal area to another, each with distinct agro-ecological conditions. Consequently, seeds saved from the previous harvest may not be adapted to the new land environment, thus contributing to seed insecurity (Haugen, 2001; Sperling et al, 2006). A summary of key findings of studies focused on seed systems in emergency contexts report that farmers who have the conditions to sow – in other words, they are not displaced or landless, generally find ways to obtain seed for at least some key crop during stress events (in Honduras: de Barbentane Nagoda & Fowler, 2003; Haugen & Fowler, 2003; in Rwanda: Sperling, 1997a,b, 2001a, 2002b; in Sierra Leone: Longley, 1997,2000, and Richards & Ruivenkamp, 1997; in Kenya: Sperling, 2000, 2002a; some initial work in Mozambique on genetic diversity: Ferguson, 2003 cited in Sperling & Cooper, 2003). A more recent Seed System Security Assessment in Haiti (CIAT, 2010) also provides some evidence that land tenure insecurity can negatively affect seed security, as after the 2010 earthquake, 10% of farmers reported concerns about land tenure changes as being one of the reasons for decreased seed use.

Intermediary determinants of seed security

There is also evidence in the literature of intermediary determinants, especially with respect to access and quality.

Seed access can be undermined, even when market channels are available, as not all households have the resources to purchase the required seeds. In the West Nile region, namely in Uganda, farmers' access to seed was largely hampered by low incomes. Low purchasing power is found to affect the affordability of seed from market sources, particularly certified seed, which is a situation that can worsen during stress periods, due to reduced household incomes/assets to finance seed purchases (Kansiime & Mastenbroek, 2016). In Sierra Leone, rice farmers who have more income, accruing from other crops sales, are those that are able to purchase seed in years when production is low, or in cases where they have large families to feed with rice (Chenoune, Belhouchette, Paloma & Capillon, 2016). Beyond economic capital to access seeds, many households rely on social capital during stress periods. A study on bean seed supply in Malawi illustrates how the lack of social capital can undermine seed access in local markets, particularly for women-headed households, as they are not part of the social network of farmers who usually have surplus production to sell. Depending on the market, this adds an additional challenge, as chronic seed-insecure households are the poorest and more prone to food shortages and are therefore those with lower purchasing power (Almekinders, 2000). In Syria, there is evidence that access to seeds and new varieties by women was undermined by cultural norms and “customary discriminatory practices” (Galiè, 2013). Additionally, seed-related social exclusion can impact already vulnerable individuals, such as widows, orphans, or tenant farmers (Bezner Kerr, 2013). Communities with weak social networks are more vulnerable to adverse conditions due to constrained access to seed (Poudel, Shrestha, Basnet, Shrestha, Sthapit, & Subedi, 2008). The availability of seeds within farmer seed networks may be depleted, as the majority of members have seed shortfalls, particularly after droughts (McGuire, 2008) or due to increasing commercialisation, labour migration, and livelihood diversification (Bellon, 2004), which together affect seed access from networks (Kansiime & Mastenbroek, 2016). In certain contexts, socio-economic exclusion affects farmers' access to seeds, which, in turn, negatively impacts on food production and security.

Food crops with high seed rates further challenge **off-market access** to seeds. Rice in rainfed lowland production systems is mainly planted through direct seedings, which requires a high seed rate, varying from 80 to 200 kg/ha (Virmani, Mao, & Hardy, 2003). Crop-specific seed rates are a critical factor for the demand for seed, where crops demanding a greater availability of seeds than others place greater pressure on the different seed access channels. Hence crops' technical idiosyncrasies can determine the level of influence of the access (and availability) dimensions of food production and security. According to Tripp (2006), in accessing seed off-farm, farmers generally seek small quantities for crops with low seed rates or with relatively small areas, in order that the cost of seed is a small proportion of the total cost of production. However, this is not the case for lowland rain-fed rice. Additionally, seeds with more availability in the formal market are usually from cash crops with a more limited selection of food crops/varieties (Tripp, 2006; FAO, 2004; Louwaars & De Boef, 2012; Almekinders, 2000). Accordingly, as informal seed systems are not market-oriented, seeds are usually produced for consumption, where some limited surplus can be bartered with neighbours or sold in local markets (FAO, 2003). Crops' idiosyncrasies determine the level of off-farm access to seed, with implications for food production and security.

The source of the seed is usually associated with its **quality**. Usually, farmed-saved seeds are of good quality (Tripp, 2000; Almerkinders, 2000; Sperling & McGuire, 2011) and do not present significant differences from seeds from the formal system (Bishaw, Struik, & van Gastel, 2012; Bishaw, Struik & van Gastel, 2013; Gibson, 2013). Research in Ghana and Zambia has shown that seed saved by farmers, or obtained from neighbours or markets is usually of acceptable quality (Tripp, Walker, Miti, Mukumbuta, & Zulu, 1998a; Tripp, Walker, Opoku-Apau, Dankyi, & Delimini, 1998b). A study looking at local bean seed quality showed that in 11 of the 13 reviewed cases, farmers' seed quality was at least as good as seed from the formal sector. Another study on cereal seed quality in many countries in Western Asia and Northern Africa showed similar results (Almekinders, 2000). A study assessing the health quality of wheat and barley from formal and informal sectors in Ethiopia and Syria found weaknesses in seed health from both sources (Bishaw et al., 2012).

A possible explanation is that off-farm seed provided by the informal seed system is subjected to some kind of quality control. Networks and social relations also are important in assessing the quality of local seed traders and may serve as a form of quality control, which is labelled by Catholic Relief Services as “social certification” (Sperling et al., 2008). An example given by Okry, Van Mele, Nuijten, Struik and Mongbo (2011) is that farmers exchange information about local rice seed traders so that possible cheating, or the provision of misinformation would spread quicklyly in their network. Farmers at informal markets assess the quality of the seed, and also the quality of the seed provider (Sperling & McGuire, 2010). Futhermore, seed exchange at local markets is regulated through “social norms of reciprocity” or “good neighbourliness” (Jones, Bramel, Longley, & Remington, 2002). Trust plays a very important role when searching for quality seed. When markets provide poor quality seed, farmers may prefer sourcing from reputable neighbours (Badstue, Bellon, Berthaud, Ramírez, Flores, & Juarez, 2007; Bicksler, Bates, Burnette, Gill, Meitzner Yoder, Ricciardi, & Srigiofun, 2012). Conversely, if farmers lack confidence in seed produced within their social network, they seek seed in local markets (Sperling & McGuire, 2010).

This does not mean, however, that there are no problems with the quality of farmers’ seed, for there are situations where farmers have sub-optimal seed quality. It has been found to be critical that appropriate varieties and good quality seed are delivered, particularly in the context of seed relief operations, because otherwise, unintended results can contribute to food insecurity (FAO, 2004; Sperling et al. 2007). Additionally, farmers under duress may be forced to rely on low-quality seed. Weltzien et al. (2001) illustrate examples of farmers’ use of low quality seed in stressful situations in Mali, Western Rajasthan, and Rwanda, including farmers sowing seed of varieties/crops that they know are suboptimal for their field conditions and sowing seed they know to be of inferior quality (germination, health status), and also buying low quality seed from the market with a considerable proportions of broken seed, pest-damaged seed, pebbles, and small twigs. This has been similarly found in Syria, where seed purchased in the market was frequently of poor quality, with a low germination rate (FAO/WFP Syria, 2015). Additionally, poorly endowed, chronically insecure seed farmers face systematic difficulties in accessing good quality seed (Longley et al., 2002; Weltzien et al., 2001). Seed system studies show that wealthier households are more likely to conserve and control their own seed, while poorer households more often supplemented their limited seed stock with whatever was available to them, which was often seed of poor quality, or varieties unsuitable for the local environment (FAO & ICRISAT, 2004). Hence seed quality is also a function of poverty.

2.2. Linkages between Seed Security, Food Production, and Food Security

In this section, I examine the literature exploring the relationship between Seed Security, Food Production, and Food Security. I do this by looking at the different strands of the literature covering these themes. As assessing seed systems is strongly dependent on crop type (and in some cases, varieties), especially in relation to their end use (e.g., for food, for sale in markets, etc.) (Weltzien, Remington, Sperling, & De Barbentane Nagoda, 2001), any literature review should ideally focus on a particular crop. The literature review below focuses on rice, where appropriate. The focus on rice is particularly relevant in the context of food security in Africa, as rice is a staple in many African countries, and in particular, in Guinea Bissau, and therefore seed security in rice is expected to have a more important effect on food security than non-food crops.

Availability "*refers to the physical quantity of seed available from all sources"*

The most direct link between seed and food security is through seed availability. As expressed by Galié (2013), seed is the first link in the food value chain. Seed is undoubtedly a vital input to farmers' production and food security (FAO, 2003; Sperling & McGuire, 2011; ICARDA, 2014) and seed can be an important entry point for promoting productivity, nutrition, and resilience among smallholder farmers (Sperling & McGuire, 2016; ICARDA, 2014; Coomes, McGuire, Garine, Caillon, McKey, Demeulenaere, & Emperaire, 2015). Despite being very well accepted by policy makers, practitioners and researchers, there are some who argue that notwithstanding the importance of seed availability for farmers' production and food security, it is rather the ownership of assets such as land, use of other inputs, and climate shocks that are more likely to affect food security than small fluctuations in seed availability (Sperling and McGuire, 2011). Sperling and McGuire (2011) argued that, based on case studies in Ethiopia and Burundi, even under chronic conditions there is always seed available both on and off-farm, as long as markets exist and there is some crop production.

Nonetheless, extensive empirical evidence from other locations confirms the instrumental role of the availability of seeds for food security. Several FAO/WFP Crop and Food Security Assessment Mission Reports for different countries[33] demonstrate that seed unavailability is a critical factor affecting food production and security. Even when seed availability is not reported as a widespread problem, seed

[33] Myanmar (2016), Sri Lanka (2017), Central African Republic (2017), Democratic People's Republic of Korea (2013) Madagascar (2013, 2016), Mozambique (2010), Tajakistan (2011)

unavailability is frequently an issue for a smaller portion of the population, including vulnerable households (FAO/WFP South Sudan, 2013; FAO/WFP Swaziland, 2015), or populations in conflict areas (e.g., FAO/WFP Sudan, 2011). Additionally, Chenoune, Belhouchette, Paloma and Capillon (2016) assessed the diversity of smallholder rice farms' production strategies and found that factors such as the availability and quality of seed explained the low and variable production and yields of rice in Sierra Leone. Their results show that farms with low and fairly low rice yields have the lowest seed rates when compared with fairly high and high-yield farms. A predominant factor affecting seeding rates is seed availability of rice from the previous season. Accordingly, unconstrained seed availability is not only critical for food production, but also for production stability.

Access "*the ability and willingness to acquire seed through cash purchase, exchange, loan, barter or use of power in social networks"*

Although access to seed is critical for production, particularly when seed from the previous harvest is not available (Tripp, 2006), Sperling and McGuire (2011) argue that seed access may also not have an effect on food security overall, as farmers can employ coping strategies, such as crop or livelihood diversification. Additionally, to justify the limited role of seed access to food production/security, these authors suggest that because only small quantities of seed are required for the majority of crops, even when seed access channels are constrained, they are unlikely to collapse entirely, with small quantities always being available. These arguments downplay the role of access to food security and are worth some discussion.

With respect to the first argument, there is no evidence in the literature to support the claim that farmers facing seed shortages for a particular crop turn to other crops and livelihood activities as a coping strategy. Conversely, there is extensive evidence that: (i) the lack of seed access affects many farmers under different circumstances (see the section above on determinants of access); (ii) undermines food production, and; (iii) low production of a staple crop has an impact on household food security, as shown below.

Lack of or constrained access undermines seed usage in the face of requirements. The coping strategies adopted by farmers with weak access to seeds are the same as those employed when farmers are faced with constrained availability, as access is a pre-condition for availability when there is a lack of unconstrained seed stock saved from the previous harvest. Looking at the effect of the access dimension of seed security on food security, Walsh and Rooyen (2015) showed that, among other factors associated with food insecurity, *Not enough money to buy seeds* was one of the chief factors hindering food availability. They also reported that 22% of households in the Rural Free State Province in South Africa considered this to be a factor which undermines their food availability.

Limited access results in decreased seed rates and/or planted area, and consequently in reduced food production and security (Chenoune et al., 2016; FAO/WFP[34]).

The effect of low production of a staple, such as rice, on food security is also well documented. In Ghana, when rice farmers experience erratic rainfall, they engage in different activities to cope with lower production, such as forming farmers' groups, borrowing food or money from relatives, and selling livestock (Al-hassan, 2011). A cross-country comparative study in India, China, and Thailand - where rice is a staple food, found that lower rice output results in major adjustments to the household food balance. They show that to cope with lower production, while also trying to secure household food consumption, households reduce their sales of rice, reduce the quantities retained as seed for the following year, increase the amount of purchased rice, substitute other crops for rice in the consumption basket, supplement their food deficit with other types of food not normally consumed, and, in the worst-case scenario, reduce their overall nutritional consumption. In fact, in Orissa, India, after undertaking these various adjustments following a drought, 54–70% of the households reduced the number of meals per day (Pandey, Bhandari, & Hardy, 2007). Another study in Orissa reports that various strategies are adopted by farmers when rice output is low, such as engaging in off-farm wage work, expanding the area under other crops, consumption loans, migration, and the sale of assets and other non-farm activities (Samal & Pandey, 2005). An extensive literature review focusing on Sahel and the Horn of Africa regions finds that households adopt several strategies for coping with food insecurity when facing low food production, such as the sale of assets, borrowing food, migration, and overexploitation of common property resources (Davies, Buchanan-Smith, & Lambert, 1991). This review shows that not only does low food production have a direct effect on the food economy of the households, but also that coping strategies to deal with food insecurity are heavily dependent on households' endowments, such as income and assets. Notwithstanding possible ex-ante strategies to mitigate seed unavailability, such as the ones suggested by Sperling and McGuire (2011), the low production of a food crop, which in turn negatively impacts food security is not always avoidable.

Sperling and McGuire's (2011) second argument with respect to the limited role of seed access on food production and security is that the demand for seeds is always small, and is consequently usually met by supply. Seed requirements are crop-specific and are related to the production system under analysis, and although this may be the case for the communities they studied, it is likely that it does not extrapolate to all crops or locations (see specific determinants of access in Section 2.2). Many smallholders in Africa produce rice mainly for their own consumption. Furthermore, the majority of

[34] Myanmar (2016), Sri Lanka (2017), Central African Republic (2017), Democratic People's Republic of Korea (2013), Madagascar (2013, 2016), Mozambique (2010), Tajikistan (2011).

rice production systems in West Africa are rainfed and require high seed rates, making the access dimension particularly challenging for this crop *in situ*ations of seed shortage, which has negative consequences for food security. In the particular context of rainfed rice production systems, assuming that seed channels do not collapse entirely, meeting demand is more challenging, and even if demand is met, farmers might not have the social or economic capital to access the necessary quantities of seed.

Quality *“includes a number of seed attributes, such as germination, physical purity, moisture content, seed health, and – for some crops – varietal purity”*

The quality dimension of seed security and its impact on food security is well documented in the literature compared to other seed security dimensions. It is widely accepted that inferior seed quality can undermine yields and reduce food availability (Larinde, 1997; Sperling & McGuire, 2011; FAO, 2007, Louwaars & De Boef, 2012). Seed quality is critical for a crop’s success, as it determines yields and stability (Kuivanen, Alvarez, Michalscheck, Adjei-Nsiah, Descheemaeker, Mellon-Bedi, & Groot, 2016; Louwaars & De Boef, 2012; ICARDA, 2014) as well as production quality and therefore contributes to food security and the value of the crop in the market (Louwaars & De Boef, 2012; ICARDA, 2014). In the particular context of rainfed rice, poor seed quality is among the key factors for low productivity, together with erratic rainfall, poor soils, socioeconomic constraints, and pest damage (Tuong-IRRI, 2000).

Seed quality together with limited availability and/or access further hinders food production. When seed quality is low, farmers tend to increase their sowing rates as a risk mitigation strategy (Sperling & McGuire, 2011; Kansiime & Mastenbroek, 2016; IRRI, 2002; FAO/WFP Syria, 2015). This is particularly relevant for rice, where farmers often use high seed rates to mitigate potential losses to rats, birds, and snails and to increase crop competition with weeds (IRRI, 2002). Increasing seed rates has implications on the quantities of seed used by farmers and increases farmers' seed requirements (Kansiime & Mastenbroek, 2016). Low seed availability, combined with low quality provides an additional challenge for food production. For example, *in situ*ations of food shortages, rice seed saved from the previous season is consumed, leaving farmers with limited availability of seed (Weltzien et al., 2001; Kansiime & Mastenbroek, 2016) which thus undermines farmers’ ability to use higher seed rates to deal with low-quality seed. Additionally, when farmers see no option other than use their seed stocks as food, not only does this have a more immediate impact on seed availability, but it can also have a more prolonged impact, as since it undermines farmers’ quality “stock” in a permanent way. Seed is not a synonym of grain, but rather seed is a subset of grain that is selected, adapted, and carefully managed, which farmers save or use specifically for planting (Louwaars & Almekinders, 2008;

Sperling & McGuire 2010). Therefore, consuming seed can undermine to some extent the quality "stock", in the form of genetic, physiologic, or physical attributes that farmers carefully kept from successive harvests, with an impact on the yields and quality in the long-run.

As such, seed quality is also a critical factor which underlies the vicious cycle of seed insecurity, low food production, and food insecurity.

Varietal suitability "the ability of farmers to have seed of crop varieties which have the characteristics that they prefer"

Varietal suitability is also a very important dimension of seed security which impacts on food security. In a similar stance as the quality issues raised above, *in situ*ations of stress, farmers use unfamiliar varieties or non-locally adapted varieties (Weltzien et al., 2001) which affects production or earnings, and consequently contributes to food insecurity (Sperling & McGuire, 2011). Furthermore, in emergency situations, farmers are offered seeds that are ill-adapted to their production environments. A Crop and Food Security Assessment in South Sudan reports that seed aid is now focused on redistributing local landraces, rather than importing exotic varieties, as since these are often not used or perform less well than indigenous material (FAO/WFP-South Sudan, 2013). Varietal suitability is also critical for reducing production variability (Haussmann, Fred Rattunde, Weltzien-Rattunde, Traoré, Vom Brocke & Parzies, 2012) and for avoiding crop failure (Dominguez *et al*, 2004; Serraj, McNally, Slamet-Loedin, Kohli, Haefele, Atlin & Kumar, 2011).

However, not only does constrained access to preferred and well-adapted varieties impact food production and security, for the loss of variety diversification can also undermine food security. Plant genetic diversity is crucial for breeding food crops and is thus one of the central preconditions for food security (FAO, 2008; Cavatassi, Lipper, & Winters, 2012). Varietal diversification is a frequent ex-ante coping mechanism (income smoothing) which farmers adopt to hedge against production risks, as it is a form of diversification which stabilises total crop output if yields of different varieties are poorly correlated (Pandey et al, 2007). In Zimbabwe, farmers prefer to use both early and late maturing varieties. Although the latter have better yields, the farmers do not want to risk having no production if the rains finish early (Sperling & Cooper, 2003). In Ethiopia, the probability of diversification increased by 16.35% for female-headed households, suggesting that women are more concerned about securing food for the family and income diversification than males (Rehima, Belay, Dawit & Rashid, 2013). In Malawi, a study looking at the impact of different innovations adopted by female farmers regarding food security, found that varietal diversity of maize resulted in a significant increase in maize output per unit area (Mutenje, Kankwamba, Mangisonib, & Kassie, 2016). However, other studies also indicated that female-headed households had a lower crop and barley variety diversification in Zambia and Tigray (Kimhi & Chiwele, 2000; Fetien, Bjornstad, & Smale, 2009). In Malawi, amongst the key strategies used to mitigate production risks of maize crop variety, diversification was mentioned by 20% of households for local maize, by 33% for open-pollinated varieties of maize, and by 37% for hybrid maize (Fofana *et al*, 2011). An extensive body of reserach finds evidence of the positive effect that varietal or crop diversity has on food production and production stability (Di Falco & Chavas, 2008; Di Falco & Chavas 2009; Di Falco, Bezabih & Yesuf, 2010; Di Falco & Chavas 2008, Smale, Hartell, Heisey, & Senauer, 1998, Widawsky & Rozelle, 1998).

Having access to a diversified pool of varieties can also allow greater flexibility in decision making to respond to changing conditions (FAO, 2008). For example, farmers in Mali use photo-period sensitive varieties as a way to manage the risk associated with variation in rain from season to season (FAO, 2003). In South Sudan, farmers are now relying on short-maturing varieties of sorghum, in order that much of the harvest can be collected before the *Quelea* bird-threat period. The Sudanese authorities used to control the population growth of these birds, but now farmers have to adapt to deal with this new risk. Therefore, varietal replacement is critical to the adaptation of cropping systems to climate change and other factors, and this can only be achieved by having access to a varietal portfolio which allows this flexibility.

In addition, there is some limited quantitative evidence of the impact of indicators of seed quality and varietal suitability on food security. From the impact evaluation empirical research studying causal links between variables of interest and food security (Babatunde and Qaim, 2010; Demeke et al, 2011; Larsena and Lilleør, 2014; Akter and Basher, 2014; Bandara et al, 2015; Jodlowski et al, 2016; Wineman, 2016; Kassie et al, 2014; Beegle et al, 2017), only Kassie et al. (2014) make reference to seed security, although not explicitly, by looking at the impact of improved maize varieties on food security in rural Tanzania. The important variable of *Improved Maize Varieties* can be an indicator of seed security, as it represents dimensions of both seed quality and varietal suitability. The results show that adoption of maize varietals increased food security and that the impact of adoption varied with the level of adoption as measured by the intensity of maize adoption.

In conclusion, varietal suitability and diversity are instrumental to maintaining and enhancing climate resilient seed systems, thus assuring the production and production stability of food crops including rice.

Overall these findings suggest that:

- Limited seed use is a result of constrained **seed availability and/or access**, with an impact on food production. Seed shortages are likely to lead to lower cultivation area and/or sowing rates, resulting in lower production and increased risks of harvest losses, thus contributing to food insecurity.
- Access and availability issues are more determinant for food production when: (i) the crop under analysis is a staple crop; (ii) seed markets are inexistent or very concentrated in more developed areas, and/or; (iii) the main seed source for the majority of these farmers is their own seed, saved from previous harvest
- Under these circumstances, if in the presence of a shock the harvest of the previous year is affected, farmers are the more likely to experience seed insecurity because of unavailability and/or lack of access.
- Although Sperling and McGuire (2011) are correct in their claim that seed availability is not an issue if there is production and if markets exist, however, this is not the case in many developing countries for various reasons, ranging from climate events such as drought, erratic rainfall, floods, to institutional factors, such as continuous political instability and conflict. In addition, access to markets can mean that farmers have no issues with seed access, however, there are a number of situations where farmers do not have access to market seed (e.g., income, social exclusion etc.).
- Seed requirements are linked with the specific crop and seeding method. Not all crops require small amounts of seed, and thus constrained availability and/or access of seed intensive crops are more likely to result in low seed rates or area planted, with consequences for food production.
- Quality and varietal suitability are also important, not only with respect to the quantity of food production, but also for quality, which makes these dimensions important in terms of the utilisation dimension of food security.
- Unconstrained use of seed is a determinant not only of average production, but in certain circumstances, it is also critical for reducing production variability and for decreasingh the risk of crop failure. The same applies to quality and varietal suitability, through different mechanisms related to suitability and quality per se, or diversity, which can have a positive effect on production (mean) and production variability (variance) and can also reduce the risk of crop failure (skewness).

- The trade-offs between these three components across the four dimensions of seed security (n.b., resilience, the fifth dimension was included across the other four dimensions) will determine the effect of seed security on production, production variability, and the risk of crop failure.

3. Seed Security, Food Production, and Food Security in Eastern Region of Guinea Bissau

A state of persistent political instability has prevailed in Guinea Bissau since its independence in 1974, resulting in a lack of development and high levels of poverty. According to the World Food Program (WFP), in Guinea Bissau, "chronic food insecurity is compounded by political instability, irregular rainfall and volatility of prices for both imported rice and local cashew nut production"[35]. Approximately 70% of Bissau Guineans live below the poverty line, with nearly 85% of the population dependent upon agriculture as their main source of income. Overall, 11% of Guinea-Bissau households are food insecure, though this figure can be as high as 51% in some areas (WFP, 2016).

Guinea Bissau has a high unexploited agricultural potential. It has 1.4 million hectares of farmland, which represents just over 30% of the country's total surface area, including 200,000 ha of lowlands, 100,000 ha of mangrove, and 1.1 million ha of upland ecology. However, this potential is underutilised. Of the 200,000 ha of lowlands and the 100,000 ha of existing mangrove, only 30,000 ha and 50,000 ha respectively are farmed. Despite its freshwater potential, the resources committed to the production of mangrove and lowland rice were estimated in 1991to be only 132 million m3. The country currently has three irrigated perimeters in the east, with total water control in the Geba Valley. The developed area is 480 ha in Contuboel, 180 ha in Carantabá, and 162 ha in Bafatá. However, currently, only 135 ha in Contuboel, 60 ha in Carantabá, and 32 ha in Bafatá are exploited. Despite the potential for food production, food security in Guinea Bissau is in a fragile equilibrium. A significantly underutilised agricultural potential, together with the degradation of natural resources and a strong dependence on cashew nut production makes farmers extremely vulnerable to international market price volatility, resulting in food availability which is insufficient to satisfy consumption needs and generates a greater dependence on imports.

Rice is a staple crop in Guinea Bissau, with nearly 56% of consumed rice originating from farmers' own production (WFP, 2016) and rice consumption per capita is one of the highest in Africa (Dawe, 2010). **Table 1** shows that Guineans consume on average 86 kg per capita per year. Only Madagascar presents a higher consumption figure, at 97 kg per capita per year. These figures illustrate well the importance of rice production systems in Guinea and its role in the food security of Guinean households.

[35] World Food Program (2017, September 29). Guinea Bissau Home Page. Retrieved from http://www1.wfp.org/countries/guinea-bissau

Table 1. African Countries with Highest per capita rice consumption

Country	Per capita average consumption (kg/year)
Madagascar	97
Guinea Bissau	86
Sierra Leone	83
Guinea	76
Senegal	74
Cote D'Ivoire	64
Mauritius	61
Comoros	57
Liberia	54
Cape Verde	50

Source: Dawe (2010)

Table 2 reports some indicators of **lowland rice production** system performance which is critical for food security in Guinea Bissau in general and for the research area (eastern Guinea Bissau- Bafatá Region. Contoboel Sector) in particular. The table shows a slight increase from 2012 to 2013, in both area harvest and production. However, there was a sharp decrease in 2014, with production falling to almost half.

Table 2. **Paddy** ***Rice in Guinea Bissau***

	2012	2013	2014
Area Harvested (ha)	114 089	135 000	85 000
Production (Tonnes)	198 504	209 717	133 000
Yield Hg/ha	17 399	15 535	15 647

Source: FAOSTAT

Although 2015 data is not available in the FAO statistical (FAOSTAT) database, the FAO (2017)[36] recently reported that at the national level, aggregate cereal production in 2015 was estimated to have increased by 28% compared to 2014—the season which this study covered. Particularly with respect to rice, which is the most important staple in Guinea Bissau, output also increased by 28% compared to 2014—a year in which output was far below the average. The FAO's country brief also reports that as a result of low rice production in 2014, combined with low producer prices for cashew nuts (the main cash crop in Guinea Bissau for 2014), the food security situation deteriorated across the country in 2015. From the semi-structured interviews I held with farmers in 2015, the low production rates that year were a result of germination failure, due to irregular rains in the planting period, which culminated in partial or total harvest loss. It is worth pointing that Guinea Bissau has

[36]Food and Agriculture Organization (2017, September 29). Guinea Bissau Country Brief. Retrieved from http://www.fao.org/giews/countrybrief/country.jsp?code=GNB

the lowest rice paddy yields compared to other rice producing West African countries. According to FAO statistical (FAOSTAT) database, in 2014 while Guinea Bissau had a yield of 15. 647 hg/ha, Mali and Senegal performance was 31,670 hg/ha and 41,417.00 hg/ha, respectively. For this year, only Guinea (Conakry) underperformed Guinea Bissau with a yield of 11,654 hg/ha.

The Sahel and West Africa – Harmonized Framework for June/August 2015 map presented in **Appendix I** provides extended evidence of the critical food security situation in that year - two months after I carried out my survey. The map shows that all northern regions of Guinea Bissau, including Bafatá, were under pressure in terms of food security. This shows how the low levels of production of rice, in particular, have contributed to food insecurity across northern regions in Guinea Bissau, including in Contuboel, the area of this case study.

Indeed, the case study area is illustrative of the broader national level picture. Figure 1, a calendar for key crops, supports the explanation of the chain of events with respect to seed, food production and food security, for the rainy growing season covered by this survey.

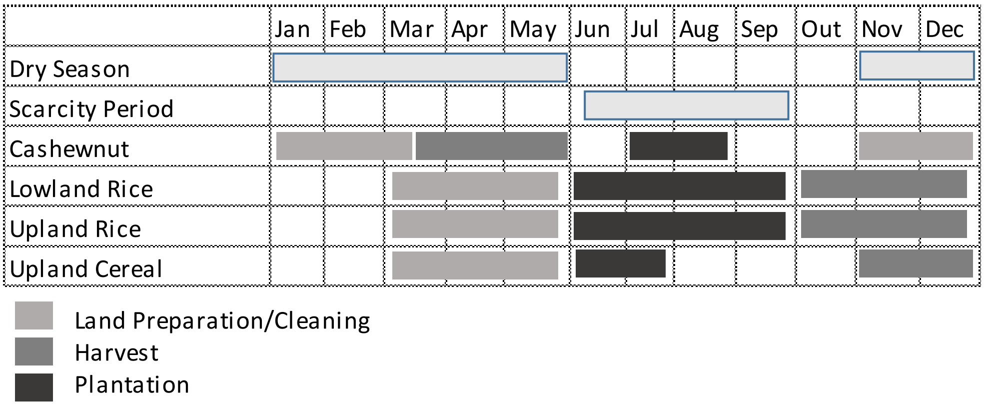

Figure 1. Crop Calendar (adapted from RGB, WFP & EU-AINDA, 2016)

I conducted my survey in February and March 2015, a few months after the 2014 rainy season harvesting period when farmers were still commencing land preparation for the next season’s crop. Data on production, namely inputs and output, is based on recall data for the previous cropping season of 2014, collected shortly after lowland rice harvest, when farmers still had a vivid memory of information. With respect to seed security indicators (dimensions of seed security availability, access and variety suitability), these refer to the period around planting of the most recent season - which was June to September of 2014. Indicators for constructing the food security index were collected using questions that asked farmers about the period covering the 7 days immediately before the interview.

In line with national-level data on rice production and food security provided above, the main cause for the lack of saved seed to plant the following year was low levels of production. Low production was due to delays in rains following the 2014 harvest, given that effective rains in most areas started very late and in insufficient quantity, impacting food security. **Figure 1** shows that the scarcity period is usually from June to September, however the low production of 2014 shifted this period to start earlier, and thus by March many households had already consumed all their rice production stock.

The impacts of low rice production were aggravated by the fact that the cashew nut harvesting period had just started and that its price was particularly low that year. It is important to note that in Guinea Bissau, cashew is traded for rice, and that trade relies largely on a barter system. This was particularly relevant for the food security situation at that time, as poor rice harvests require the import of rice, however falling real cashew prices and slightly increasing rice prices decreased the ratio of cashew to rice prices and reduced households' bartering positions— which was an extremely important shift in the terms of trade in Guinea-Bissau and one which left many households in a situation of food insecurity.

Evidence of the negative impact of low rice production combined with the disadvantageous cashew nut-rice terms of trade is revealed in my case study from the many interviewed households which reported feeling food-insecure at the time of the survey. I followed the same approach as the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) to assess subjective food insecurity, including nine questions in the questionnaire regarding the frequency-of-occurrence of specified conditions. The question was: "In the past seven days, how many days have you or someone in your household had to", followed by the nine different situations (see Table 3), in order to capture the full scope of food insecurity from the purely psychological to the more physical feelings of hunger.

Table 3. Food Security: Frequency of answers

Variable	Mean	Std. Dev.	Min	Max
Eat less preferred food	99.03%	0.10	0	1
Limit food variety	99.03%	0.10	0	1
Limit food quantity	79.68%	0.40	0	1
Reduce the number of meals	56.45%	0.50	0	1
Restrict adult food consumption so that children can eat	66.13%	0.47	0	1
Borrow food or asked for food to family and friends	21.94%	0.41	0	1

Go with no food to eat of any kind	22.58%	0.42	0	1
Go to sleep hungry at night	64.84%	0.48	0	1
Go a whole day and night without eating	25.48%	0.44	0	1

Table 3 shows that *Eat less preferred food, Limit food variety, and Limit food quantity*, was experienced approximately by 99%, 99%, and 80% respectively of the households. Less frequent, but also reported by the majority of households were *Reduce the number of meals* (57%)*, Restrict adult food consumption so that children can eat* (66%), and *Go to sleep hungry at night* (65%).

Table 4. Food Security: In the past seven days, how many days have you or someone in your household had to:

Variable	Mean	Std. Dev.	Min	Max
Rely on less preferred foods?	3.56	1.52	0	7
Limit the variety of foods eaten?	3.55	1.65	0	7
Limit the portion size at meal-times?	2.41	1.94	0	7
Reduce number of meals eaten in a day?	1.56	1.74	0	6
Restrict consumption by adults in order for small children to eat?	2.69	2.63	0	7
Borrow food, or rely on help from a friend or relative?	0.46	0.96	0	5
Have no food of any kind in your household?	0.38	0.79	0	4
Go to sleep at night hungry because there is not enough food?	1.64	1.59	0	6
Go a whole day and night without eating anything?	0.38	0.74	0	4

Table 4 reports the number of days during the past seven day period that the household experienced any of the specified food insecurity situations. The top three situations with the highest number of days of occurrence in a week are: *Relying on less preferred foods*, *Limiting the variety of foods eaten food variety* and *Restricting consumption by adults in order for small children to eat*. On the other hand, *Having no food of any kind in your household* and *Going a whole day and night without eating anything,* which indicates more severe food insecurity, with lower frequencies of occurrence. Overall, these results reflect that farm households were suffering from food insecurity at the time of the survey.

4. Empirical Strategy

The previous section provided an overview of the situation of seed security, food production, and security in Guinea Bissau, particularly in the case study area in the Bafatá region. This section now presents the empirical strategies used to estimate the determinants of the three different seed security measures and the effect of seed security on food production, in order to provide a broader understanding of the dynamics between these different concepts.

4.1. Determinants of Seed Security

I employ three different methods to estimate the determinants of different seed security measures: OLS, Village-Level Random Effects, and Village-Level Fixed Effects. The first measure to be analysed is the Seed Security Index (SSI), which captures the five dimensions of seed security as described in the first chapter: availability, access, variety suitability, quality, and resilience. As an alternative, this is also measured based on the first two principal components of: (i) Biodiversity and Social Capital, and; (ii) Availability, Social Access & Utilisation (quality and varietal suitability), respectively (See Chapter 2 for detail on the index construction and alternative indices). The purpose of analysing these two uncorrelated indices is to provide a more disaggregated picture of the determinants, and particularly the effects of Seed Security, by looking for different and complementary expressions of seed security which are specific to this region of Guinea Bissau.

Before moving into presenting the estimators, it is worth pointing out that the lack of temporal data constrains the use of other types of estimators that could measure different sources of endogeneity, such as the difference in differences estimator. Notwithstanding the fact that the majority of the independent variables are either time-invariant, households' and farmers' characteristics, or are lagged variables, and this contributes to eliminating the possibility of simultaneity bias. However, a possibility of unobservable variables exists at the village level which might influence both seed security outcomes and some of the dependent variables. For example, villages' agro-ecological conditions could influence both cultivated area and seed security outcomes. To deal as much as possible with this issue, given the limitations of the data, I use village-level variables in both the OLS and Random Effects models. The Fixed Effects model includes village level fixed effects, aiming to remove possible bias accruing from village level unobserved variables. Therefore, the causal interpretation of these results must be approached with caution, as despite efforts to deal with it, there is still a possibility of bias due to endogeneity.

Below I briefly describe the strategy used to estimate the determinants of the seed security measures. Following Wooldridge (2015) on the use of **fixed effects**, I used the following approach to control for village level fixed effects:

$$y_{it} = \alpha + x_{it}\beta + v_i + \epsilon_{it}.(1)$$

For each i (village), I average this equation over each village and obtain:

$$\bar{y}_i = \alpha + \bar{x}_i\beta + v_i + \bar{\epsilon}_i \text{ (2)}$$

where $\bar{y}_i = \sum_t y_{it}/T_i$, $\bar{x}_i = \sum_t x_{it}/T_i$ and $\bar{\epsilon}_i = \sum_t \epsilon_{it}/T_i$ (2)

Subtracting (2) from (1), it must be equally true that:

$$(y_{it} - \bar{y}_i) = (x_{it} - \bar{x}_i)\beta + (\epsilon_{it} - \bar{\epsilon}_i) \text{ (3).}$$

These three equations provide the basis for estimating β. The fixed-effects estimator, which is also known as the within estimator, is obtained using OLS to estimate (3). The important thing about equation (3) is that the unobserved effect a_i has disappeared. The fixed effects estimator is unbiased under a strict exogeneity assumption of the explanatory variables. That is to say, the idiosyncratic error u_{it} should be uncorrelated with each explanatory variable across all villages. As noted earlier, this estimator might be biased, since it is not possible to control for time invariant differences between rice farmers, which may pose an endogeneity problem.

The **random-effects estimator** is a (matrix) weighted average of the estimates produced by the between and within estimators. In particular, the random-effects estimator turns out to be equivalent to the estimation of:

$$(y_{it} - \theta\bar{y}_i) = (1-\theta)\alpha + (x_{it} - \theta\bar{x}_i)\beta + (1-\theta)\, v_i + (u_{it} - \theta\bar{\epsilon}_i) \text{ (4)}$$

where θ is a function of δ_v^2 and δ_ϵ^2 . If $\delta_v^2 = 0$, this means that v_i is always 0, and $\theta = 0$ and (1) can be estimated by OLS. Conversely, if $\delta_\epsilon^2 = 0$, this means that ϵ_{it} is 0 and $\theta = 1$ and therefore the fixed effect estimator (within) provides us with all the information available (which is a $R^2 = 1$)

The assumptions underlying this approach are as follows:

- The fixed effect estimator (3) is conditional on the sample, in that the v_i is not assumed to have a distribution, but is instead treated as being fixed and estimable.
- The Random Effect estimator (4) requires that v_i and $\bar{x}_i$ are uncorrelated and follows the assumption of the OLS estimator, whereby when v_i and $\bar{x}_i$ are correlated, the estimator

cannot determine how much of the change in $\bar{y}_i$, associated with an increase in $\bar{x}_i$, can be assigned to β, versus how much can be attributed to the unknown correlation. This would suggest the use of an instrumental-variable estimator, z_i, which is correlated with $\bar{x}_i$, but uncorrelated with v_i, although this approach is not used here.

4.2. Effects of Seed Security on Food Production

To estimate the effect of seed security on food production, I use a generalised propensity-score matching as follows. In setting the expected outcome, Food Production at alternative levels of the Seed Security treatment is reported from the estimated dose-response function. This approach follows the one used in many empirical studies, such as: in the estimation of the impact of the adoption of maize on food security in Tanzania (Kassie et al., 2014); in the impact of the adoption of improved wheat varieties on household food security in Ethiopia (Shiferaw, Kassie, Jaleta, & Yirga, 2014); in the effect of access to tractor services on the income growth of farm households in Nepal (Takeshima, Adhikari, & Kumar, 2016); the impact of growth on exports in Germany and the United Kingdom (Fryges, 2009), and; the direct and indirect effects of foreign direct investment on firm productivity (Girma, Gong, Görg, & Lancheros, 2015).

In the evaluation literature, the main econometric approaches used to analyse selection bias in cross-sectional data include: propensity score matching; generalised propensity score matching in a continuous treatment framework, and; instrumental variable approaches. The propensity score matching is not considered here, as the treatments under consideration are continuous. Both generalised propensity score matching and instrumental variables approaches can be performed, using a continuous variable as treatment. However, there is no suitable instrumental variable[37] in the dataset to allow an instrumental variables approach. This leaves generalised propensity score matching as the only feasible approach. Compared to generalised propensity score matching, which only controls for observed heterogeneity, the instrumental variable (IV) approach has the advantage of controlling for unobserved heterogeneity. Nonetheless, IV approaches are not immune to critique. Young (2017), studying a sample of 1,400 instrumental variables regressions in 32 papers, found IV

[37] The initial estimation strategy for estimating the effect was to use year of birth of the "mulher grande" of the family, who is the oldest women within the household, as an instrumental variable. The reasoning was that the "mulher grandes" are the ones in the household with the most knowledge of seeds and that they are particularly responsible for seeding and harvest activities. This variable was thought to be a good candidate for an IV, as year of birth could be considered to be random, and these women were expected to have an effect on seed production through their impact on seed security. Nonetheless, the weak-instrument-robustness tests showed that this is a "weak instrument". This means that this instrument does not have a high degree of explanatory power for the jointly endogenous variable (seed security) and that its use leads to a problem of inference.

estimators to be falsely significant and more sensitive to outliers when compared to OLS, and that they were often irrelevant, while also finding little evidence that OLS estimates are substantively biased. There is also a growing body of literature which shows that identification might be possible in the presence of unobserved confounders under particular settings (e.g., Altonji et al., 2005; Oster, 2014; Krauth, 2016). It is unquestionable that unconfoundedness is a strong, untestable assumption, however, I am confident that the choice of covariates, as well as the particular context of this research, makes unconfoundedness plausible for use in my study, for the following reasons. First, one possible source of endogeneity might be farming ability, or farm specific characteristics, as both can affect seed security, as well as food production. Therefore, to minimise the chances of omitted variable bias, I include two variables which are thought to capture farming ability, namely: years of schooling and experience ratio. Secondly, following Sherlund, Barrett and Adesina (2002), I also control for heterogeneous environmental production conditions, such as soil quality and fragmentation. Altitude and slope are not included, as plots within the same village are all in the same location in lowland valleys, and therefore differences in altitude and slope are minimal. Thirdly, with respect to simultaneity bias, such bias is unlikely, as all the seed security measures are constructed with variables prior to rice harvest, and therefore cannot be affected by production. Finally, in terms of individual unobserved, as this sample of lowland farmers is characterised by a great deal of homogeneity in terms of socio-economic, farm, and farming characteristics, it is therefore not implausible to assume that likely unobserved factors might also be relatively homogeneous across farmers and farms, thus reducing the likelihood of bias due to confoundedness. Furthermore, through customary tenure institutions, each adult female in the household owns a plot, which means that the household lowland farm is composed of different plots, according to the number of women. Women in the household are usually wives of the household head or of other male members of the household. This means that the "ability pool" in a household, which could not be observed, can be said to be randomly assigned, as farming or seed selection abilities are unlikely to be a marriage selection criteria and that there is probably considerable homogeneity. Therefore, for the reasons mentioned above, there are strong reasons to believe the assumption of unconfoundedness in this setting.

The hypothesis that I test through this empirical strategy is that different seed security measures have a positive effect on households' rice food production. To test this hypothesis, I use the method developed by Hirano and Imbens (2004). Hirano and Imbens (2004) define the propensity function to be the conditional density of the actual treatment, given the observed covariates. The dose-response function at a particular treatment level t can be estimated by using a partial mean approach by three steps. In the first step, I estimate the score $r(t, x)$,

$$g(T_i)\ |X_i \ \sim \ N\{h(\gamma, Xi), \sigma^2\}$$

where $g(Ti)$ is a suitable transformation of the treatment variable, and $h(\gamma, Xi)$ is a function of covariates with linear and higher-order terms, which depends on a vector of parameters, γ. I use a lognormal distribution to model the level of seed security (Ti) given the covariates. The GPS was then estimated based on the parameters calculated in this equation. It is worth pointing out that the GPS has a balancing property similar to that of the standard propensity score as it ensures that the covariates are balanced across treatment categories within strata with the same value of $r(t, x)$, with the probability that $T = t$ does not depend on the value of X_i. Accordingly, the assignment for treatment is unconfounded, given the GPS. The **second step** consists of estimating the conditional expectation of the outcome to be a function of the treatment level T and the generalised propensity score R:

$$\phi\ \{E\ (Yi \mid Ti, Ri)\} \ = \ \psi(Ti, Ri;\ \alpha)$$
$$= \ \alpha_0 \ + \ \alpha_1 \ \cdot T_i \ \ + \alpha_2 \cdot T_i^2 \ + \ \alpha_3 \cdot T_i^3 \ + \ \alpha_4 \cdot R_i \ \ + \alpha_5 \cdot \ R_i^2 \ + \ \alpha_6 \cdot R_i^3 \ + \ \alpha_7 \ \cdot \ T_i \ \ \cdot \ R_i \ ,$$

where $\phi\ (.)$ is a link function which relates the predictor, $\psi(T_i\ , R_i\ ;\ \alpha)$ to the conditional expectation $E\ (Yi \mid T_i\ , R_i\ )$. As the link function depends on the nature of the outcome variable, in my case, I use a linear regression model, as my outcome is measured as a continuous variable and with a quadratic approximation, as shown in detail in Section 5.2. Finally, in the **third step**, I estimate the dose-response function $\mu(t) \ = \ E\ [\beta\{t, r(t, X)\}]$ by averaging the conditional expectation $\beta\{t, r(t, X)\}$ over the GPS at each level of treatment. These steps are presented in more detail in **Appendix III.**

5. Results and Discussion

5.1 Determinants of Seed Security

Table 5 presents the results of the determinants of seed security, using three different measures of seed security, namely: (i) The Seed Security Index; (ii) The Biodiversity and Social Capital Index, and; (iii) The Availability, Social Access, and Utilisation Index. In **Appendix II**, descriptive statistics for the variables used in the models are presented. All the variables included in the model represent household and farm-level characteristics, based on the literature review covering the structural determinants of Seed Security presented in **2.1**. For details on the empirical strategy, see **4.1.**

Table 5. Determinants of Seed Security: Pooled, Fixed, and Random Effects Models

Variables	Seed Security Index			Biodiversity and Social Capital Index			Availability, Social Access and Utilisation		
	Pooled	Village RE	Village FE	Pooled	Village RE	Village FE	Pooled	Village RE	Village FE
Female Head of Household	-0.025 (0.012) ***	-0.03 (0.009) ***	-0.032 (0.011) ***	-0.894 (0.387) ***	-0.894 (0.189) ***	-0.83 (0.236) ***	0.699 (0.201) ***	0.463 (0.13) ***	0.422 (0.136) ***
Age Head of Household	-0.001 (0.001)	0 (0.001)	0 (0.001)	0.023 (0.026)	0.021 (0.036) ***	0.019 (0.033)	-0.068 (0.021) ***	-0.026 (0.017)	-0.021 (0.017)
Family size	0.004 (0.001) ***	0.004 (0.001) ***	0.004 (0.001) ***	0.089 (0.027) ***	0.084 (0.022) ***	0.079 (0.025) ***	0.049 (0.023) ***	0.043 (0.027) ***	0.042 (0.028) ***
Dependency ratio	-0.005 (0.001) ***	-0.005 (0.001) ***	-0.005 (0.001) ***	-0.095 (0.031) ***	-0.098 (0.027) ***	-0.102 (0.027) ***	-0.147 (0.028) ***	-0.114 (0.044) ***	-0.11 (0.047) ***
Education	0.003 (0.003)	0.002 (0.002)	0.002 (0.001)	-0.035 (0.084)	-0.014 (0.082) ***	0.023 (0.052)	0.186 (0.055) ***	0.07 (0.085)	0.062 (0.085)
Lowland farmers experience ratio	0.012 (0.003) ***	0.011 (0.003) ***	0.009 (0.003) ***	0.403 (0.107) ***	0.377 (0.118) ***	0.276 (0.103) ***	0.014 (0.093)	0.109 (0.042) ***	0.146 (0.054) ***
Ethnic Minority	0.029 (0.006) ***	0.014 (0.007) ***	0.005 (0.001) ***	1.028 (0.184) ***	0.546 (0.33) ***	0.182 (0.05) ***	0.154 (0.123)	-0.017 (0.041)	-0.028 (0.035)
Long-run economic status	-0.001 (0.002)	-0.002 (0.001)	-0.003 (0.001)	-0.012 (0.044)	-0.02 (0.053) ***	-0.029 (0.051)	-0.051 (0.042)	-0.061 (0.032)	-0.059 (0.031)
Landless	0.009 (0.005)	0.012 (0.008)	0.012 (0.009)	0.588 (0.158) ***	0.523 (0.141) ***	0.314 (0.155)	-0.336 (0.164) ***	0.148 (0.361)	0.236 (0.345)
Area Owned	0.014 (0.004) ***	0.015 (0.006) ***	0.017 (0.005) ***	0.616 (0.134) ***	0.574 (0.162) ***	0.56 (0.1) ***	0.481 (0.097) ***	0.567 (0.221) ***	0.58 (0.229) ***
Distance to plot	0.003 (0.002)	0.002 (0.003)	0.005 (0.003)	0.102 (0.057)	0.107 (0.08) ***	0.139 (0.098)	-0.021 (0.056)	-0.009 (0.06)	0.03 (0.046)

Soil Quality	0.003 (0.005)	0.003 (0.006)	0.004 (0.007)	-0.122 (0.138)	**-0.045 (0.148)** ***	0.113 (0.164)	**0.343 (0.115)** ***	0.168 (0.143)	0.124 (0.14)
Tenure Security	0.013 (0.004)	0.006 (0.005)	-0.002 (0.003)	0.394 (0.127)	**0.32 (0.151)** ***	0.084 (0.09)	**-0.269 (0.127)** ***	**-0.417 (0.105)** ***	**-0.395 (0.115)** ***
Constant	0.009 (0.029)	0.018 (0.033)	0.015 (0.034)	-3.777 (0.896)	-3.271 (0.981)	-2.805 (0.91)	1.265 (0.707)	0.262 (0.363)	0.014 (0.402)

Robust Standard errors in parentheses. Signifiance code: *p<0.10, **p<0.05, ***p<0.[38]

Determinants of Seed Security Index

The *Gender of the head of household* and *Dependency ratio* coefficients are negative and statistically significant under the three model specifications. While *Family Size, Lowland farmers experience ratio, Ethnic Minority,* and *Area Owned*, have a positive and significant effect on seed security, consistently across the three models. Overall, these results are consistent with previous qualitative work on seed security, where farmers with more access to labour and able to plant more area, are more likely to be seed secure (Cromwell, 1996; Sperling et al., 2006).

Being a female head of household is also negatively associated with seed security, which is consistent with previous literature, which finds that disadvantaged group, such as women-headed households and ethnical minorities, are usually the poorest and the most seed-insecure households in rural communities in developing countries (GTZ & CGN, 2000). However, unlike previous evidence, belonging to an ethnic minority seems to have a positive effect on seed security level. Nevertheless, in Chapter 1 it was noted that the sample captured very few households who can be actually labelled as being minority. Accordingly, what these results show is that belonging to the second largest ethnic group in the region plays a positive role in seed security.

With respect to farmers' experience, the results show that more experience translates to greater seed security. Oliveira, Havik, and Schiefer (1996) noted that older women are those who are responsible for managing seed storage, sowing activities, and seed selection during harvest. Furthemore, in many of the semi-structured interviews conducted in the context of this research, the "Mulher grande", which is the local name for the elderly women, were reported to be the ones with the most knowledge of seeds, and to particularly have the responsibility for sowing and harvest activities, particularly seed selection. As reported in one of the interviews, before harvest, older women immediately go into the fields to look for the "most beautiful" panicles.

[38] See Appendix V for Model Comparison Tests: F test (FE vs OLS); Breusch and Pagan LM Test RE vs OLS; Hausman Test RE vs FE

Other determinants of seed security found in the literature, such as Tenure Insecurity (Sperling et al 2006; Haugen, 2001) and Poverty (Almekinders, 2000; Sperling et al, 2006) do not seem to apply to this type of seed security lowland rice. The *Long-run economic status* coefficient has a negative sign in the three model specifications, although none of the coefficients is statistically significant. While tenure security has a positive coefficient for both the OLS and Random effects model specifications, it is also not statistically significant. In the absence of markets, it is plausible to assume that poverty, captured by low long-run economic status, would not have a negative association with the Index through components such as availability, social access, quality, and varietal suitability, although it would rather be a negative determinant, through the economic access and resilience related variables. A possible explanation for this is the limited scope of the asset index labelled *Long run economic status*, which might not be fully capturing the long run socio-economic status of households in a way that contributes to endowment-related variables within the Seed Security Index. It is also worth noting that this measure can be seen to be a combination of wealth index and seed security index, where only the latter is the actual form of seed security being experienced by the farmers in the study. Hence by design, these results reflect a conflation of determinants of wealth and seed security, possibly masking the identification of *de facto* determinants of seed security. As already noted, the analysis of the determinants was also conducted with additional seed security measures, to allow a more disaggregated understanding of the issues at hand, as follows.

Determinants of Biodiversity and Social Capital

Area Owned has a positive and significant association with Seed Security across all model specifications. Household labour availability, which is reflected by *Household size and Dependency ratio*, is an important determinant of this type of seed security, whereby households with more members and fewer dependents are more seed secure, across all model specifications. This indicates that factors of production such as labour and land are also critical for biodiversity and the social capital form of seed security. Di Falco et al. (2010) also found a positive relationship between land and labour and crop biodiversity. In addition, Benin, Smale, & Ehui (2004) show that the size of land and the proportion of males in the household is positively associated with intra-crop diversity. The positive role of the area on varietal diversity was also found in similar studies in Ethiopia, Peru, Mexico, and Hungary (Smale, 2005). Research in Ethiopia, Peru, and Mexico found a strong and positive association between the quantity of labour and intra-crop diversity (Smale, 2005).

Female-headed households are negatively associated with this form of seed security. This finding is more generally supported by previous research on both seed security (GTZ and CGN, 2000) and on biodiversity in particular (e.g., Smale, 2005; Di Falco et al, 2010).

These results also agree with earlier research, which finds extensive evidence of the role of experience for varietal or crop diversity (Smale *et al,* 2005). This finding has important policy implications for this result, particularly in the context of shifting farming practices and climate change. Farmers' experience builds both from and on a body of indigenous knowledge[39] about crop genetic resources, climate shifts, and terrain. The critical role of both indigenous knowledge (Orlove et al. 2000; Riedlinger and Berkes 2001; Berman and Kofinas 2004) and crop genetic diversity (Swiderska, Reid, Song, Li, Mutta, Ongogu, Mohamed, Oros, & Barriga, 2011; Parry et al., 2007; Nyong, Adesina, & Elasha, 2007) to climate adaptation is well established in the literature. Traditional knowledge and genetic diversity are usually interlinked and are mutually reinforcing (Parry et al., 2007; Swiderska et al., 2011; Nyong et al., 2007). Farmers understand and appreciate the value of diversity, not only as a natural gene bank for resilient crop varieties, but also as a key farming practice to reduce risk (Swiderska *et al*, 2011). Farmers in developing countries are dramatically impacted by climate change, critically affecting crop production and food security, however, they are very well placed to identify resilient crop species and varieties for adaptation which are critical to adopt. In Guinea Bissau, agro-diversity and traditional knowledge seem relatively untouched. In contrast, the formal seed system is poorly developed and is unable to diffuse improved varieties, as a consequence of years of conflict and political instability following independence which has resulted in a national agricultural research system with weak capacity and meagre resources[40]. From semi-structured interviews and focus groups with rice farmers', older women were incontestably identified as being the community guardians of lowland farming knowledge and expertise. However, several farmers shared their concerns that this knowledge may start to dissipate, as younger farmers are losing their interest in rice farming.

Ethnic minority sign is again positive and is a statistically significant determinant of the biodiversity type of seed security. Intra-specific crop diversity maintained by farmers is more than the portfolio they own, and it builds largely on the management processes and the knowledge associated with the varietal diversity. To this end, the results suggest that the Mandinga ethnic group might be better equipped to manage diversity.

Determinants of Availability, Social Access and Utilisation

The results of the determinants of Availability, Social Access and Utilisation are very similar to those of the former indices for *Family size, Dependency ratio, Lowland farmers experience ratio,* and *Area*

[39] According to Thrupp (1987), indigenous knowledge system are adaptive skills of local people, which are usually derived from extensive experience that is usually communicated through 'oral traditions' and is learned through family members and generations.

[40] Only two farmers where planting Nerica (a hybrid variety promoted by the Africa Rice Center in partnership with INPA - the national agricultural research institute)

Owned. Researchers such as Cromwell (1996) and Sperling et al. (2006) find that households experiencing seed insecurity suffer from economic marginalisation, as they are usually poor, with little land and labour available.

Although these results are broadly consistent with previous findings, the *Long-run economic status* variable, which should capture poverty issues, is not significant in any of the models. A possible explanation for this may lie with the fact that Availability, Social Access, and Utilisation are related variables which are not determined by endowment-related variables. This is supported by several studies which show that income or assets positively affect economic related access to seeds (e.g., Kansiime & Mastenbroek, 2016; Chenoune, et al, 2016). However, there is no evidence that farmers' wealth influences social access to seed. With particularly regard to utilisation aspects, in the literature no evidence is found of the positive link between seed quality/variety suitability and farmers' economic status. Poorly-endowed, chronically-insecure seed farmers are likely to face difficulties in accessing good quality seed (Longley et al., 2002; Weltzien et al., 2001; FAO & ICRISAT, 2004) and varieties suitable for their local environment (FAO & ICRISAT, 2004). Although this can be found in the context of existing seed markets, when markets are underdeveloped, being better off could have little influence in obtaining good quality seeds and suitable varieties. This is the case of the lowland rice production systems where input markets are virtually inexistent, and therefore income has no role in providing farmers with better quality seeds or with more suitable varieties.

Ethnicity has a negative sign in the fixed effects model, although it is not significant. The results from previous measures suggest that the Mandinga ethnic group is associated with seed security measures which are more heavily weighted on wealth and biodiversity-related variables, however, belonging to this ethnic group, or any other, does not seem to contribute to availability, social access, or the utilisation type of seed security. On the whole, ethnicity-linked seed security is well aligned with the previous qualitative research, whereby households' and farmers' characteristics are associated with seed security, however my results differ from previous research, especially for determinants associated with disadvantaged groups, such as women-headed households (GTZ & CGN, 2000) and also with respect to tenure security (Haugen, 2001; Sperling et al, 2006). The results show higher levels of seed security for female-headed households than for their male counterparts. There are some case studies in the food security field which show female-headed households with no statistically significant difference, or even as being better off in terms of food security, when compared to male-headed households. Quisumbing et al. (2001), using a household survey for 10 developing countries, found no higher incidence of poverty among the female-headed households in two-thirds of the countries, whereas Mallick & Rafi (2010) found no statistical difference in the food security between these two types of households. Another study found that female-headed households experience higher levels of economic agency, physical capital empowerment, psychological empowerment, and farm financial management skills empowerment were more likely to be food secure (Sharaunga, Mudhara, & Bogale, 2016). As quantitative research on determinants of seed security is virtually inexistent, looking for evidence stemming from similar fields provides some insights that the worse-off female-headed household stereotype does not fit in every type of outcomes and in every context. The tenure security coefficient being negative and statistically significant is a more puzzling result, as it is very unclear which mechanism could be driving this result. This is something worth exploring in future research.

5.2 Effects of Seed Security on Food Production and Security

The effect of Seed Security Index on Food Production

Using the potential outcome approach to causal inference (Rubin, 1974), I estimate a continuous dose-response function which estimates the effect of each value of the dose of the Seed Security Index on Food Production (for a detailed estimation strategy, see Section 3.2). Following Lee's (2005) "must cases" rule for the choice of covariates to overcome potential selection bias, I chose pre-treatment variables that can affect both treatment and outcome as cofounders. Based on a literature review of both Seed Security (Cromwell, 1996; GTZ & CGN, 2000; Almekinders, 2000; Haugen, 2001; Sperling et al, 2006) and Agricultural Production Determinants (Di Falco et al, 2010; DiFalco & Chavas, 2009; Sherlund et al., 2002), I controlled for the variables presented in **Table 6.**

Table 6. Covariate balancing after accounting for the generalised propensity score (GPS): t-statistics for equality of covariate means

	Treatment Interval 1 [-.013, 0.080[			Treatment Interval 2]0.080,0.110]			Treatment Interval 3]0.110,0.200]		
	Mean Diff.	**Std. Dev**	**t-value**	**Mean Diff.**	**Std. Dev**	**t-value**	**Mean Diff.**	**Std. Dev**	**t-value**
Female Head of Household	-0.04	0.03	-1.56	0.01	0.03	0.38	0.03	0.03	0.99
Family Labour	0.40	0.31	1.29	0.63	0.34	1.85	-1.16	0.32	-3.63
Age	2.35	1.82	1.29	-2.19	1.85	-1.19	0.44	2.09	0.21
Lowland farmers experience ratio	0.07	0.08	0.88	-0.16	0.09	-1.83	0.08	0.08	1.05
Education Head of Household	0.05	0.12	0.40	0.20	0.12	1.66	-0.21	0.12	-1.66
Ethnic Minority	0.06	0.05	1.21	0.04	0.06	0.61	-0.02	0.04	-0.70
Long-run economic status	-0.28	0.17	-1.64	0.25	0.17	1.44	-0.01	0.19	-0.06
Area Owned	0.15	0.07	2.08	0.05	0.09	0.62	-0.10	0.07	-1.55
Soil Quality	-0.02	0.06	-0.40	0.04	0.06	0.65	0.02	0.07	0.25
Ln Distance Plot	-0.07	0.11	-0.67	0.12	0.13	0.90	-0.18	0.14	-1.30

After the GPS matching, the balancing property satisfied at a level lower than 0.01, which provides an indication that the balancing property is supported by the data. I then estimated the following model:

$$Y_t = Index\ SS_{t-1} + Index\ SS_{t-1}{}^2 + GPS + GPS^2 + Index\ SS_{t-1} * GPS$$

Table 7. Conditional expectations of outcomes estimated using generalised propensity scores

Food Production	Coefficient	Std. Err.
SS Index	**-7655.39**	2818.36***
SS Index^2	**39430.02**	13241.27***
GPS	-53.65	39.96
GPS^2	-0.36	2.28
SS Index*GPS	**693.15**	158.08***
_cons	**676.11**	170.89***

Signifiance code: *p<0.10, **p<0.05, ***p<0.

Table 7 shows the results of regressions where Rice Production was regressed for the functions of GPS and treatment *T* (the Seed Security Index). As in Hirano and Imbens (2004), the coefficients in these regressions have no real meaning, however the statistical significance of the coefficients for GPS indicates that estimations of the treatment effects on outcomes are biased if GPS is excluded. As shown in **Table 7**, the GPS is not statistically significant for GPS and GPS squared, indicating that the GPS might not be reducing potential bias, as desired.

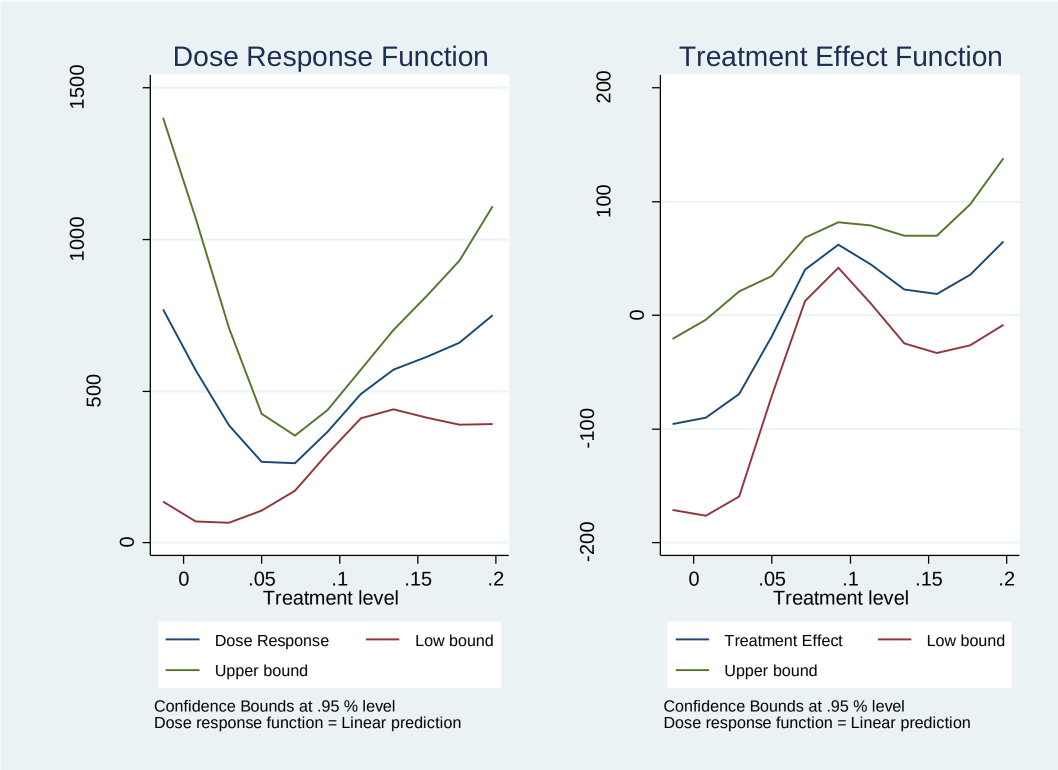

Figure 2. Dose-Response and Treatment Effects of Seed Security Index on Food Production: (a) Dose Response Function, (b) Treatment Effect Function

Figure 2 (a) shows the average dose-response function of SSI on Food Production, where the top and bottom dashed lines are 95 % confidence upper and lower bound intervals obtained via bootstrapping. As Fig. 2(a) shows that the Dose-response function of Seed Security on Food Production is U-shaped. For treatments below 0.05, Food Production is a decreasing function of Seed Security. The curve falls away swiftly from around 800 kilograms for a low treatment to around 0 (zero), until it reaches a small plateau at around 250 kilograms, and then it inflects, sharply increasing at an increasing rate from that point. The left panel shows the marginal treatment effect of an incremental increase of 0.01 in the SSI. Figure 2(b) illustrates that an incremental change of 0.01 has a fixed marginal effect of around -100 kg for low treatment values around 0 (zero). This means that an “additional dose” of seed security reduces production by 100kg for households with a treatment level slightly below 0 (zero). From approximately 0.5 level of treatment, the marginal effect becomes positive, which shows that an “extra dose” of SSI has a positive marginal effect on Food Production for treatment above that level of SSI. The highest marginal effects occur at treatment levels of 0.1 and 0.2, where an incremental change of 0.01 respectively results in a marginal effect of an additional 50kg.

Overall, this graph suggests a threshold effect at a value around 0.06 of the Seed Security Index, which is the point from where the Seed Security Index stops having a negative effect on Food Production. As the *Seed Security Index* variable has some indicators for household endowment indicators, such as income and assets, this graph could be capturing an endowment effect. Although these indicators are a reasonable part of the Index from a theoretical point of view, the use of the index as a dependent variable in this context to identify a causal effect of seed security on food production might not be warranted. This could explain the difficulty in interpreting the results, as the endowments components integrated into the index can have another effect on food production, apart from improving seed security.

To disentangle how the different dimensions affect food production, the following analysis looks at the effect on seed security on an alternative index, which is mainly constructed from *seed* specific variables, including Availability, Social Access, and Utilisation (quality and varietal suitability). By seed related components, I mean that I use an alternative index which virtually excludes income and asset related variables, leaving only seed specific variables. The rationale for this analysis is also driven by the conclusions in Chapter 2, where including income and asset-related variables was important, as, in theory, they contribute to seed security in a potential sense, however, in practice, this is not the case. The limited market in the Contuboel region for lowland seeds results, in practice, that neither income, nor assets improve the seed security status of female lowland farmers, but that availability, utilisation, and access in its social component do.

The effect of Availability, Social Access, and Utilisation (AAU) Index on Food Production

I follow the same approach as above to control for pre-treatment variables which can affect both treatment (the Availability, Social Access, and Utilisation Index) and outcome (Food Production) as covariates to control for possible selection bias.

Table 8. Covariate balancing after accounting for the generalised propensity score (GPS): t-statistics for equality of covariate means

	Treatment Interval 1 [-2.30,-0.63[			Treatment Interval 2]-0.63, 0.71]			Treatment Interval 3]0.71,0.267]		
	Mean Diff.	**Std. Dev**	**t-value**	**Mean Diff.**	**Std. Dev**	**t-value**	**Mean Diff.**	**Std. Dev**	**t-value**
Female Head of Household	0.06	0.03	1.79	-0.03	0.03	-1.01	0.01	0.02	0.43
Family Labour	0.49	0.35	1.40	-0.03	0.30	-0.09	-0.28	0.32	-0.89
Age	-2.13	1.73	-1.23	0.75	1.63	0.46	0.86	1.79	0.48
Lowland farmers experience ratio	-0.07	0.08	-0.89	0.19	0.08	2.47	-0.07	0.09	-0.75
Education Head of Household	0.38	0.12	3.14	-0.51	0.10	-4.88	0.28	0.09	2.99
Ethnic Minority	0.02	0.06	0.25	0.13	0.06	2.30	-0.10	0.06	-1.70
Long-run economic status	0.29	0.18	1.60	-0.37	0.16	-2.30	0.34	0.18	1.85
Area Owned	-0.09	0.09	-0.98	0.42	0.07	6.01	-0.22	0.07	-3.24
Soil Quality	0.06	0.06	1.05	0.01	0.06	0.13	-0.05	0.06	-0.84
Ln Distance Plot	0.14	0.13	1.06	-0.05	0.11	-0.42	0.12	0.13	0.96

The GPS matching is very effective in balancing the covariates within treatment intervals, as the balancing property is satisfied at a level lower than 0.01, which provides a reasonable indication that the balancing property is supported by the data. The following model is estimated:

$$Y_t = \; AAU\_Index\,SS_{\,t-1} + \; AAU\_Index\,SS_{\,t-1}{}^{2} + GPS + GPS^2 + \; AAU\_Index\,SS_{\,t-1} * GPS$$

Table 9. Conditional expectations of outcomes estimated using generalised propensity scores

Food Production	**Coefficient**	**Std. Err.**
AAU Index	99.25	46.52***
AAU Index^2	175.55	30.25***
GPS	4197.13	1256.13***
GPS^2	-6059.75	2309.33***
AAU*GPS	642.86	200.48***
_cons	-406.47	187.37***

Signifiance code: *p<0.10, **p<0.05, ***p<0.

As shown in **Table** 9, as GPS, GPS squared, and GPS interacted with the treatment are all statistically significant, this is a good indication that assessing the effects of Availability, Social Access, and Utilisation Index on rice production, through GPS reduces biases.

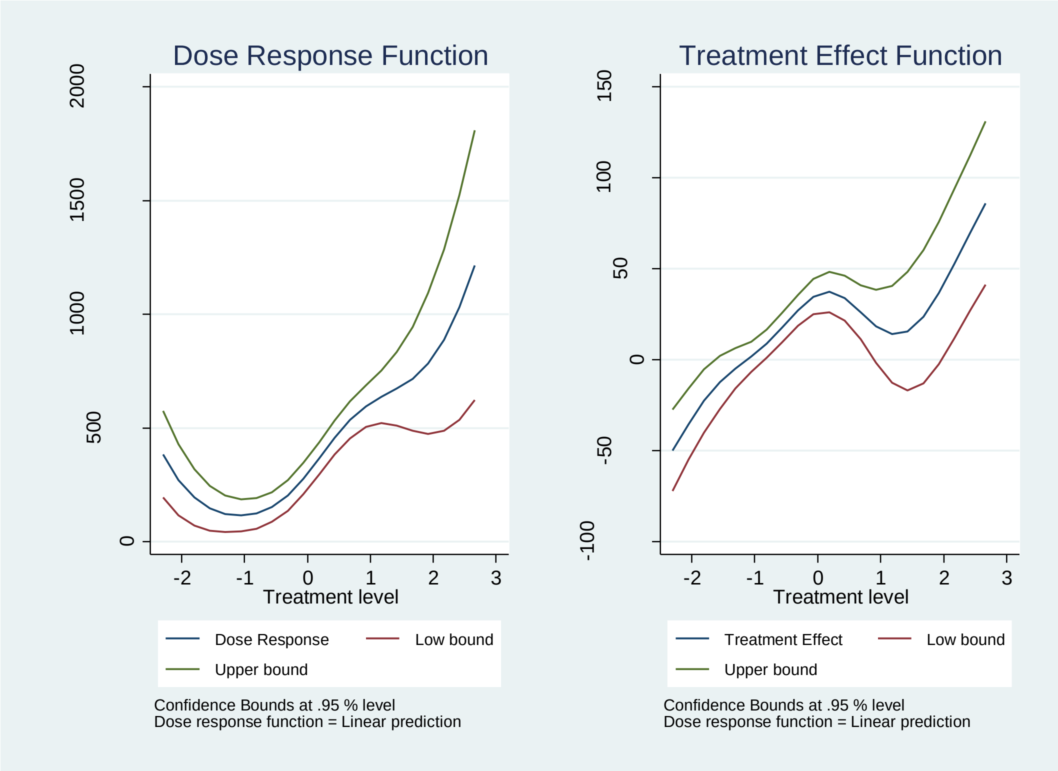

Figure 3. Dose-Response and Treatment Effects of Sub Seed Security Index on Food Production: (a) Dose Response Function, (b) Treatment Effect Function

Figure 3 (a) shows that for very low treatment values, Food Production is a decreasing function of this type of Seed Security. The effect of the treatment on Food Production slightly decreases, until it reaches a plateau of around -1.5 of the treatment score, followed by an inflexion point of around -1. From this point, the Food Production increases sharply with an increasing rate until around the 1 level of the treatment, and from that point the function increases at a decreasing rate. Overall, this graph shows in this Index, for levels above -1, any small improvement in household seed security level is the will result in a large increase in production. For example, an increase of the index score from 0 (approx. 100 kg) to 1 (300kg) results in an increase in rice production of 200 kg . **Figure 3** (b) represents the marginal effect, which is small and decreasing for low levels of treatment, which means that an additional 0.01 dose of the Availability, Social Access, and Utilisation Index has a negative, or null effect on production for treatment values below approx. -1. For treatment values from this point on, the marginal effect is always positive. From a 0 (zero) treatment score, the gains of an additional 0.1 unit decrease steadily until 1.5, after which they start to increase again more sharply. The maximum marginal effect is at an Availability, Social Access and Utilisation Index score of 2.8, for which farmers gain 75kg for an additional 0.1 treatment unit.

Discussion

The results of the dose-response function of **Availability, Social Access, and Utilisation (AAU)** help us gain a deeper understanding of the relationship between **Seed Security Index and Food Production**. By comparing these two dose responses graphs (2a and 3a), it appears that there is some type of income/assets related effect for low levels of seed security. When weights from income and assets related variables are dramatically reduced, the negative effect which is shown in the first graph for low levels of seed security reduces significantly. It is worth pointing out that most of the agricultural income that female farmers gain accrues mainly from horticultural activities. A possible explanation for these results is that engaging in additional agricultural activities, such as horticulture, might negatively affect rice production. These results could well reflect that small increases in engagement in alternative agricultural activities come with a cost to lowland rice production. It also suggests that these costs are higher for low levels of engagement, while for high levels of engagement, this effect is not as detrimental for rice production. On the whole, these results are an indication that the complete index dose response at lower levels could be driven by an omitted variable bias. Lower levels of farming managerial efforts in lowland production associated with engagement in cash crop production result in a cost for rice production. This cost could be diminishing at a decreasing rate, with no (negative) effect on food production for higher levels of cash crop income, which justifies the threshold for higher levels of seed security. An alternative explanation is from a certain point, these costs are simply offset by other seed security variables which contribute more than proportionally to food production. The comparison of the steepness of the two curves after each respective threshold, suggests that this latter interpretation, or maybe a combination of them both, could be the case, as the effect of seed security on production is much larger for the Availability, Social Access, and Utilisation Index than the aggregated Seed Security Index. These results are not fully informative with regards to the relationship between seed security and food production, however they provide useful insights into the possible relationship between the engagement of women in cash crops and diversification of livelihoods of food production.

There is evidence in the literature to show that the relationship between cash crops and food crops can be both positive and negative, depending on context and on the specific crops. Some authors have found synergies between cash crop commercialisation and food crop production through interlinked markets and regional spillovers (e.g., Dorward, Kyddand, & Poulton, 1998; Govereh and Jayne, 2003). However, research shows that there is a trade-off between cash crop and food production, with an impact on food security (Ethiopia: Adane, 2009 and Ghana: Anderman et al, 2014). Cash crop production cannot improve the production and productivity of food crops, particularly in areas where there are no spillover effects and interlinked markets (Govereh et al., 1999); Maxwell and Fernando, 1989) which is the case of Guinea Bissau. Unlike other case studies (e.g., Dorward et al, 1998, Govereh and Jayne, 2003 on cotton), the horticulture market does not attract potential buyers who provide inputs to cash crop producers and increase production and productivities of both crops. Interlinked markets are usually a result of policies, for example, when there are no arrangements for market interlinkages, there is little chance of synergies between cash and food crops. With respect to regional spillover effects, these usually result from commercialisation schemes that result in a second round of investments in a particular area, which provides benefits to farmers across a region. The introduction of horticulture as a cash crop in the west region of Guinea Bissau was mainly promoted through development projects supported by local NGOs, with donor funding and with low market orientation, making these types of regional spillover effects less likely. Despite these results not being fully informative about the relationship between seed security and food production, they do indicate useful insights about the possible relationship between female engagement, cash crops, and diversification of livelihoods on food production. This hypothesis is aligned with case studies in Ethiopia (Adane, 2009) and Ghana (Anderman et al, 2014), which show that in the absence of an interlinked market, the trade-offs between cash and food crops contribute negatively to food production. Nevertheless, the results from the aggregated Seed Security Index need to be approached with caution, as **Table 7** suggest the GPS might not be very effective in reducing bias.

With respect to **the effect of the Availability, Social Access, and Utilisation Index** on food production (Figure 3), there is also a threshold effect. For low levels of seed security, there is a relatively small negative effect on food production until a threshold at a -1 score, from where the relationship becomes positive. These results suggest that in the first part of the seed index measure, the risk of failure is reduced at a cost in terms of average production. This cost is reflected by cancelling out the positive effect of seed security on food production for low levels of seed security. As shown in Section 2.2, seed security contributes not only to production, but also to production stability to a great extent, especially through availability, quality, and varietal suitability dimensions, which are included in the Availability, Social Access, and Utilisation Index. To deal with climate uncertainty, farmers' seed requirements (availability) are high, as seed must be available at planting time, and also during the growing season, as germination failure might oblige farmers to re-sow in order to avoid harvest failure. Furthermore, varietal suitability contributes to production stability, as certain traits confer tolerance or resistance to abiotic and biotic stresses which occur due to climatic variation or climatic (Haussmann *et al*, 2012), as well as to avoiding crop failure (Dominguez *et al.*, 2004; Serraj, *et al.*, 2011). The same effect occurs with seed quality, which is also found to be critical for production stability (Kuivanen, Alvarez, Michalscheck, Adjei-Nsiah, Descheemaeker, Mellon-Bedi, & Groot, 2016; Louwaars & De Boef, 2012; ICARDA, 2014). In Section 3, it was mentioned that majority of farmers had to use all their seed, as the late rains resulted in extended germination failure. Accordingly, farmers increased the quantities of seed used to avoid harvest losses. These results show that seed security improvements, which represent an increase in varietal suitability, combined with quality and less-unconstrained use (by means of availability and social access), helped diminish harvest losses and ultimately, crop failure, up to a threshold level of seed security, beyond which benefits managed to surpass these costs, resulting in a positive effect on food production. Farmers maintain a relatively steady output as a strategy to deal with risks of production variability and failure.

Literature examining the effects of seed security on food production is virtually inexistent. However, as described in Section 2.2 and 4.2, varietal diversity is a key resilience indicator of seed security. An extensive body of research looks into biodiversity as an input factor for the agricultural production function (Di Falco & Chavas, 2007; Di Falco & Chavas 2009; Di Falco et al., 2010; Di Falco & Chavas 2008, Smale et al., 1998, Widawsky & Rozelle, 1998), from which some insights can be brought to this discussion and support the interpretation above. Some of these studies have found evidence of the contribution of crop biodiversity to the mean and the variance of agricultural yields (Smale et al., 1998, Widawsky et al., 1998, Smale et al., 2003, Di Falco & Perrings, 2005, Di Falco et al. (2007), and also to the role of diversity on the skewness of the distribution of crop yields (Di Falco & Chavas 2006, 2009). The estimated dose-response function, particularly in the case of the Availability, Social Access, and Utilisation Index, suggests that similar mechanisms could be driving the relationship between seed security and food production. In Section 2.2, I examined the mechanisms by which the different dimensions of seed security contribute to food production, and ultimately to food security. This analysis suggests that seed security management provides risk management motivation. Under uncertainty, risk-averse decision-makers can, for example, have the incentive to increase seed rates in order to avoid crop failure in the face of a weather event, and use better-adapted varieties with lower yields to decrease production variability, as well as increase the diversity of varieties to reduce the risk of crop failure. Therefore the trade-offs that exist between these three components (mean, variance, and skewness) across the four dimensions of seed security (n.b., resilience, the fifth dimension was included across the other four dimensions) are likely to determine the size of the effect of seed security on production for different levels of treatment, as presented in **Figure 3**.

Finally, one of this paper's hypotheses is that increased food production would ultimately translate into food security, and this deserves some additional discussion. In Section 3, I present data and findings from other studies in the country that support this claim. The FAO's country brief[41] reports how the food security situation deteriorated across the country in 2015, as a result of low rice production in 2014. The Sahel and West Africa – Harmonized Framework for June/August 2015 Map which is presented in **Appendix I**, shows that all northern regions of Guinea Bissau, including Bafatá, were under pressure with respect to food security. Finally, evidence of the negative impact of low rice production combined with the disadvantageous cashew nut-rice terms of trade is also revealed in my case study by the high incidence of food insecurity among the interviewed households at the time of the survey (See **Table 3 Food Security: Frequency of answers** for details). On the whole, these results corroborate this chapter's findings that low levels of production contributed to food insecurity in the study site. Notwithstanding the fact that additional agricultural income, such as horticulture income, can translate to greater access to food, and consequently to higher levels of food security, it is argued that this was insufficient to overcome the food gap left by low levels of food production.

[41]Food and Agriculture Organization (2017, September 29). Guinea Bissau Country Brief. Retrieved from http://www.fao.org/giews/countrybrief/country.jsp?code=GNB

6. Conclusions and Policy Implications

This chapter examined three research questions to shed some light on the determinants of seed security, as well on the mechanisms underlying relationships between seed security, food production, and food security, and also the effects of seed security on food production.

The first research question asked is **"what are the determinants of seed security?"** Size of household, dependency ratio, area owned, and farmers' experience ratio are all consistently significant across the different measures. These results are consistent with previous research which reports household labour, land (Cromwell, 1996; Sperling et al. 2006), and experience (Smale, 2005) as contributing positively to seed security. Female-headed households are associated with lower levels of seed security for the Seed Security Index and Biodiversity and Social Capital Index, which is also aligned with evidence from the literature (GTZ & CGN, 2000). Female-headed households are associated with higher levels of seed security, as measured by the Availability, Social Access, and Utilisation Index. This result suggests that these households could have an advantage in the case of some of the availability, social access, seed quality, and varietal suitability variables, when compared to households where there is a male head. With respect to ethnicity, the first two indices show a positive association between seed security and the second largest ethnic group - the Mandinga, whereas for the latter index, ethnicity does not contribute to seed security. Overall, given the small number of households from ethnical minorities in the sample, is not possible to assert whether belonging to an ethnic minority is disadvantageous in terms of seed security. Poverty, as measured by the variable Long run wealth, does not seem to have a role in seed insecurity across the three measures. This is mainly a result of the fact that wealth is associated with security where markets exist, whereby farmers can experience access-based seed security, otherwise, being better off only translates into a potential form of seed security. Finally, the tenure security variable is only significant for the Availability, Social Access, and Utilisation Index - with a negative sign, which is in contrast with previous literature, as higher perceptions of the risk of expropriation is associated with greater seed security.

The second research question is **"what are the mechanisms underlying the relationships between seed security, food production, and food security?"** As a result of extensive analysis, Section 2 of this chapter has shown evidence of the possible mechanisms that link seed security to food security, namely through food production. **Availability** is defined as being farmers who possess seed at the desired quantity and at the right time. This aspect is instrumental for food security, as seed is a key input for food production, with increased importance in the context of food crops. Furthermore, access, which is defined as the ability and willingness to acquire seed through cash purchase, exchange, loan, barter, or social networks, was also found to be extremely important. Access is particularly relevant in the context of unavailability at the farm level, when farmers have to resort to (or rely on) off-farm seed through different possible sources. Constrained **use** of seeds, by means of limited availability and/or access, affect food production in the same manner as constrained availability, limiting sowing rates and area planted and undermining food production, stability, and consequently food security**. Varietal suitability** is found to contribute to food production and security by two means. First, suitable varieties are better adapted to farmers' agro-ecological conditions, especially in terms of disease and pest resistance. By being more resistant, those desired varieties and/or varieties that are better adapted to marginal environments are less vulnerable to shocks and also reduce the risk of production losses, resulting in an increase in production and production stability. A second mechanism through which varietal suitability affects food production and ultimately food security is through diversity. Varietal diversity is expected to contribute positively to productivity and production stability. Accordingly, varietal diversity is key to the resilience dimension of seed security. Thirdly, having access to a diversified pool of varieties was found to enable greater flexibility in decision making to respond to changing conditions. **Seed quality**, which includes a number of seed attributes, such as germination, physical purity, moisture content, and seed health, is also a determinant for yields, production stability, and production quality. Therefore, seed quality contributes to food security, directly through the availability and quality of food by means of food crop production, and also indirectly through the market value, particularly in the case of cash crops. Seed quality also influences food security in combination with availability and via seed requirements, as intensifying seeding rates is a frequently-used risk mitigation strategy for dealing with low-quality seed. In turn, increasing seed requirements puts pressure on food stock, either by reducing availability and the stability of grain for food consumption, or by reducing available food/seed to market.

The third research question is **"what is the effect of seed security on food production?"** The estimated dose-response function of the Seed Security Index (aggregated) indicated a non-monotonic relationship between seed security and food production. For example, when the GPS approach used a quadratic term of the Seed Security Index on the outcome model, the effect of increasing Seed Security between 0 and 0.5 appears to reduce food production, rather than increase it. A possible explanation for this result is the unsuitability of the complete index to study the relationship between seed security and production, as it conflates different dimensions in a single measure, with different effects on food production and it therefore provides results that are difficult to interpret. Nonetheless, comparing the results of the dose-response functions for the two different indexes, the Seed Security Index and Availability, Social Access, and Utilisation Index provided some insights into what might be driving these results. Comparing the two graphs suggests that income and asset livelihood variables drive a more negative effect on production, which is particularly evident for low levels of seed security. It is possible that this negative effect might be the result of trade-offs between cash crop and food crop production. When the scope of the dimensions included in the index are reduced with the Availability, Social Access, and Utilisation dimensions, the results are broadly in line with the hypothesis of this paper - that seed security has a positive effect on food production. Accordingly, across most of its values, the Availability, Social Access, and Utilisation Index has a positive effect on food production. That is to say, greater seed security leads to increased food production, at least at moderate to high levels of security. Furthemorer, this also suggests the existence of causal pathways through which this effect occurs. Nevertheless, these results need to be approached with caution, as the methods employed do not deal with potential endogeneity, which that can lead to biased estimates.

Policy Implications

The findings on the determinants of seed security are a reflex of the limited options for seed that lowland farmers experience in Contuboel sector that stems from a very immature seed market, and possibly some homogeneity among farmers' in the sample, which translates into factors of production such as land, labour, and experience being the main determinants of seed security across all measures. On the whole, the policy implications of these results are very much the same as those suggested in Chapter 2 - where different types of seed security should be translated into different approaches to deal with the specificities of the different farmers' profiles that are associated with these types of (in)security, targeting seed market-oriented approaches where the socio-economic status of farmers is higher, with initiatives such as supporting agro-multipliers as commercial producers while constructing a value chain by linking them to local markets and general traders. Implement participatory approaches - such as participatory plant breeding and varietal selection to promote the diffusion of improved varieties and the quality of well performing local varieties, where availability is constrained and seed quality and varietal suitability are not aligned with farmers' needs. Diversity should be maintained where it exists and should be used to promote exchange from areas of higher to lower diversity.

Notwithstanding the potential role of female agricultural income in enabling the access dimension of food security, production of rice seems to be critical for attaining food security, particularly when low production is associated with the decline of the terms of rice-cashew-nuts trade. Therefore, improving seed security to achieve higher levels of rice self-sufficiency is a key policy implication, notwithstanding complementary policies which target improved access to food. The growing acknowledgement among the government and development partners of the importance of rice production for attaining greater levels of food security has been translated into many projects which focus on improving rice self-sufficiency. An example is the African Development Bank project entitled "Rice Value Chain Development Project in the Regions of Bafatá and Oio", which is aligned with the country's strategic orientations, which "will help to improve productivity and production in the flagship sector for food security: rice" (p. 4, AfDB, 2017) and the EU-AINDA - Integrated Actions in Nutrition and Agricultural Development (see Chapter 4 for more details on these projects). Therefore, these results provide evidence which consubstantiates these political options and informs policymakers about the need to include seed security of particular food crops as a critical component of food security policy as a whole.

In terms of implications for future research, in line with the recommendations of the previous chapter, there is a need to analyse a richer set of variables, particularly with respect to varietal suitability and quality, which would allow the construction of dimension-specific sub-indexes to investigate specific determinants of different dimensions, as well enable the further disentangling of the effect of specific dimensions on food production. Furthermore, the availability of temporal data can not only identify problems that arise from possible sources of endogeneity, but it can also provide insights into the dynamics underlying seed security, food production, and food security. Panel data would be particularly useful for examining the effect of dimension-specific sub-indexes and their effect on mean, variance, and skewness of production. These results also raised flags with regard to possible trade-offs between engagement in cash crops and food production, which should also be further investigated in future research, not only for the impact on food production, but also for how a greater engagement of women in cash crops could benefit, or not, food security as a whole. Female headed households and negative perceptions over risk of expropriation are found to be positively associated with seed security in its availability, social access and utilization dimensions. Despite not being classified as a minority, Mandinga ethnical group seem to be positively associated with seed security. Since these findings differ from previous research, gaining a deeper understanding of the mechanism underlying these results should also be subject of future research.

On the whole, this chapter is the first attempt in the literature to estimate the determinants of seed security quantitatively, as well as to provide quantitative evidence of the positive link between seed security on rice production. This is of particular significance in the context of rural areas, where the informal seed system is the main source of food crop seeds and where subsistence farming is prevalent and food production is undoubtedly a key contributor for food security. As suggested both in Chapter

2 and in this chapter, implementing and refining policies targeted at improving seed security would be instrumental for increasing total production, production stability, and consequently food security.

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Appendix II. Descriptive statistics on the variables used in the models

Table 10. Descriptive statistics on the variables used in the Models

Dependent Variables	Description and Units	Mean	St. Dev.
Production	Quantity of Lowland rice harvested in 2014 (ton)	0.14	0.04
Seed Security Index	Seed Security Index (Dimensions: Availability, Access, Varietal Suitability and Resilience)	0.07	0.02
Seed Security Sub-Index	Seed Security Index (Dimensions: Availability and Social Access (income related variables not included in the index; Sub-index of the two first components[42])		
Varietal Diversity	Margalef Richness Index for varietal diversity=Number of varieties divided by the logarithm of rice area cultivated	-0.81	0.09
Independent Variables			
Gender	Gender of household head (0 = male; 1 = female)	0.05	0.22
Age	Age of household head (years)	52.20	14.41
Family size	Total family size (number)	52.20	14.41
Dependency ratio	Members whose age is greater 65 and less 15 years on total household size	14.06	4.97
Education	Education level of household head (years of schooling)	8.11	3.87
Lowland farmers experience ratio	Ratio between rice farming experience and age	0.58	0.91
Ethnic Minority	Ordinal variable ranging from Majority (1) to Minority (3) ethnic groups	0.59	0.66
Long-run economic status	Socio-economic status measured by Socio-Economic Status Index[1]	0.00	1.55

[42] See Chapter 1 for details on index construction and sub-indexes (Section 3.3)

Long-run economic status reduced	Socio-economic status measured by Socio-Economic Status Index[1] without asset related variables	0.00	1.35
Landless	Land Ownership Status (1 = Landless Farmer; 0=Farmers Owns Land)	0.14	0.35
Area Owned	Area owned (ha)	0.88	0.64
Area Cultivated 2014	Area cultivated in 2014 rainy season (hectares)	0.72	0.55
Distance to Plot	Natural logarithm of the distance of the plot to the household (meters)	6.44	0.96
Soil Quality	Soil quality dummy variable (0=poor or average, 1=rich)	2.21	0.47
Risk of Expropriation	Tenure security dummy variable measuring levels of risk of expropriation/land being removed(0=medium or high, 1=low)	2.43	0.74

Appendix III. Dose Response Function Definition and Assumptions

Definition 2.1 GPS: Let $r(t, x)$ be the conditional density of the treatment given the covariates $r(t, x) = f_{T|X}(t \mid x)$. Then the GPS is $R = r(T, X)$. The GPS has a balancing property similar to the standard propensity score, which means that in strata with the same value of $r(t, x)$, the probability that $T = t$ does not depend on the value of X: $X \perp I(T = t) \mid r(t, x)$, where $I(\cdot)$ is the indicator function. In combination with a suitable unconfoundedness assumption, this balancing property implies that assignment to treatment is unconfounded, given the GPS (Hirano and Imbens, 2004).

Theorem 2.1. Weak unconfoundedness given the GPS: Suppose that assignment to the treatment is weakly unconfounded, given pre-treatment variables X:

$$Y\,(t) \perp T\,|X\; for\; all\; t\; \in\; T$$

Then, for every t,

$$f_T\,\{t \mid r(t, X), Y\,(t)\} = f_T\;\{t \mid r(t, X)\}$$

This theorem means that if the treatment assignment mechanism is weakly unconfounded, given the covariates, then it is also weakly unconfounded given the GPS. Using this theorem, Hirano and Imbens (2004) show that the GPS can be used to eliminate any biases associated with differences in the covariates.

Theorem 2.2. Bias removal with GPS: Suppose that assignment to the treatment is weakly unconfounded, given pre-treatment variables X. Then

$\beta(t, r) = E\,\{Y\,(t) \mid r(t, X) = r\} = E\,(Y \mid T = t, R = r)$ and $\mu(t) = E\,[\beta\{t, r(t, X)\}]$

Steps to estimate the Dose response function

Step 1. Modeling the conditional distribution of the treatment given the covariates

The first step is to estimate the conditional distribution of the treatment given the covariates. It is assumed that the treatment, or its transformation has a normal distribution conditional on the covariates:

$$g(T_i)\,|X_i\; \sim\; N\{h(\gamma, Xi), \sigma^2\}$$

where $g(Ti)$ is a suitable transformation of the treatment variable, and $h(\gamma, Xi)$ is a function of covariates with linear and higher-order terms, which depends on a vector of parameters, γ. The choice of the higher-order terms to include is only determined by the need to obtain an estimate of the GPS that satisfies the balancing property.

Step 2. Estimating the conditional expectation of the outcome given the treatment and GPS

In the second stage, a model of the conditional expectation of the outcome, Y_i , given T_i and R_i is conducted as a flexible function of its two arguments. A polynomial approximation of order not higher than three is used to approximate this response function. Specifically, the most complex model that is considered is:

$$\phi\{E(Yi \mid Ti, Ri)\} = \psi(Ti, Ri;\ \alpha)$$
$$= \alpha_0 + \alpha_1 \cdot T_i + \alpha_2 \cdot T_i^2 + \alpha_3 \cdot T_i^3 + \alpha_4 \cdot R_i + \alpha_5 \cdot R_i^2 + \alpha_6 \cdot R_i^3 + \alpha_7 \cdot T_i \cdot R_i$$

where $\phi(.)$ is a link function which relates the predictor, $\psi(T_i, R_i; \alpha)$, to the conditional expectation, $E(Yi \mid T_i, R_i)$. Note that α is the vector of the estimated parameters. Assuming that the main effects of T_i and R_i cannot be removed, it results in 18 possible sub-models. All these models are defined and estimates for each of them are obtained by using the estimated GPS, $\hat{R}_i$. When fitting the selected model, the nature of the outcome variable—binary, categorical (nominal or ordinal), or continuous— is taken into account by choosing the appropriate link function.

Step 3. Estimating the dose–response function

The last step consists of averaging the estimated regression function over the score function evaluated at the desired level of the treatment. Specifically, in order to obtain an estimate of the entire dose-response function, an estimation of the average potential outcome for each level of the treatment is conducted as follows:

$$E\{\widehat{Y(t)}\} = \frac{1}{N}\sum_{i=0}^{N} \hat{\beta}\,\{t, \hat{r}(t, X_i)\} = \frac{1}{N}\sum_{i=0}^{N} \varphi^{-1}\left[\hat{\psi}\{\,t, \hat{r}(t, X_i); \hat{\alpha}\}\right]$$

where α is the vector of the estimated parameters in the second stage.

Finally, the dose–response function is estimated according to an algorithm. This algorithm carries out the following steps:

1. Estimate the GPS, verify the normal model used for the GPS, and test the balancing property
2. Estimate the conditional expectation of the outcome, given the treatment and the GPS
3. Estimate the average potential outcome for each level of the treatment the user is interested in.
4. Estimate standard errors of the dose-response function via bootstrapping.
5. Plot the estimated dose-response function and, if requested, its confidence intervals.

Appendix IV. Model Comparisons

Tests	SSI		Biodiversity & Social Capital Index		Availability, Social Access and Utilization	
F test that all $u_i = 0$ FE vs OLS	0.0000	FE	0.0000	FE	0.0000	FE
Breusch and Pagan LM Test RE vs OLS	0.0000	RE	0.0000	RE	0.0000	RE
Hausman Test RE vs FE	**0.0000**	**FE**	**0.0000**	**FE**	**0.0000**	**FE**

The results are the same across different models and specifications. For all models, the f-statistic testing whether the hypotheses that all coefficients are equal to zero is rejected. Given the plausibility of the unobserved village level variables that contribute to differences in seed security between households, random and fixed effects specifications are more suitable under this assumption. The highly significant likelihood ratio test provided by STATA after running fixed effect regressions supports this assumption, as it rejects the hypotheses that residuals within village (u_i,) are equal to zero. While in the case of the Breusch and Pagan Lagrangian multiplier test for random effects model we reject the null hypothesis that $Var\ (u_i) = 0$, which implies the presence of unit (village) random effects, and therefore pooled OLS should not be the appropriate model specification[43]. To decide between fixed or random effects, I ran a Hausman test, where the null hypothesis is that the preferred model is random effects versus the alternative model the fixed effects. This test compares an estimator $\hat{\theta}_1$, which is known to be consistent and an estimator $\hat{\theta}_2$, which is efficient under the assumption being tested (i.e., that the errors (u_i) are correlated with the regressors, and the null hypothesis is they are not). The null is that estimator $\hat{\theta}_2$, is an efficient and consistent estimator of the true parameters and that if thisd is the case, then there should be no systematic difference between the two estimators. From the Hausman test we reject the null hypothesis that the unobserved individual level effects are not correlated with the other covariates. This implies that the fixed-effects estimator should be the one to be used for all models specifications.

[43] When estimated with robust standard errors option, this test is not computed

Chapter 4. Seed Sovereignty in a context of State Fragility: The Case of Rice in Guinea Bissau

This chapter aims to provide a more holistic view of the seed sector in Guinea Bissau, by characterizing the seed governance and system situation in Guinea Bissau, and examine the risks and opportunities of the international/regional legal and institutional frameworks to farmers' rights, while putting the former chapters in a broader context.

ACRONYMS

ABS: Access and Benefit Sharing

ACBIO: African Centre for Biosafety

ACOBES: Consumer Protection Association

AFSTA: African Seed Trade Association

APALCOF: Associação das Produtoras e de Auto-Promoção para Luta contra Fome

APRODEL: Asociación de Profesionales para el Desarrollo Local y la Promoción Económica

ARGIS: AfricaRice Genebank Information System

ASIWA : Alliance for Seed Industry in West Africa

AU: African Union

BEDE: Biodiversity Exchange and Dissemination of Experiences

BSF: Benefit-sharing Fund

CBD: Convention on Biological Diversity

CGIAR: Consultative Group for International Agriculture Research

CILSS : Permanent Inter-State Committee against Drought in the Sahel

CNA : Competent National Authority

CNEV: National Catalog of Species and Varieties

CNPS: National Council of Seeds and Plants

COASP: West African Peasant Seed Committe

COPAGEN: Coalition for the Protection of African Genetic Heritage

CORAF: Conseil ouest et centre africain pour la recherche et le développment agricoles

CPI: Corruption Perceptions Index

CSO: Civil Society Organisations

DGDR: Directorate General of Rural Development

DUS: Distinctness, Uniformity and Stability

EAC: East African Community

ECOWAS: Economic Community of West African States

EPA: Economic Partnership Agreement

EU: European Union

FAO: Food and Agriculture Organisation of the United Nations

FCFA: Franc CFA

GB: Guinea Bissau

GDP: Gross Domestic Product

GS: Governance System

IAD: Institutional Analysis and Development

IARC: International Agricultural Research Centers

IBAP: Instituto da Biodiversidade e das Áreas Protegidas

IMVF: Instituto Marquês de Valle Flôr

INPA: National Institute for Agriculture Research

IP: Intellectual Property

IPR: Intellectual Property Rigths

ISU: Seed Science Center of Iowa State University

ITPGRFA: International Treaty on Plant Genetic Resources for Food and Agriculture

LPDA: Letter of Agricultural Development Policy

LVIA: Associazione Internazionale Volontari Laici

MAT: Mutually Agreed Terms

MLS: Multilateral System

MRDA: Ministry of Rural Development and Agriculture

NARS: National Agriculture Research System

NGO: Non-governmental organisation

NSTA: National Seed Trade Associations

OAPI: African Organisation for Intellectual Property

OAU: Organisation of African Unity

PAIGC: Partido Africano para a Indepência da Guiné e Cabo

PGR: Plant Genetic Resources

PGRFA: Plant Genetic Resources for Food and Agriculture

PIC: Prior Informed Consent

PNIA: National Agricultural Investment Program

PROAGRI: Promoção para o Desenvolvimento Agrario na Guiné-Bissau

PVP: Plant Variety Protection

PVS: Participatory Varietal Selection

RESSAN: Civil Society Network for Sovereignty and Food and Nutrition Security in Guinea-Bissau

RGG: Republic of Guinea Bissau

ROPPA: West Africa Farmer and Producer Organisations Network/Réseau des Organisations Paysannes et des Producteurs de l'Afrique de l'Ouest

RS: Resource System

RU: Resource Unit

SADC: Southern African Development Community

SCSLF: Southern California Spiny Lobster Fishery

SES: Social-ecological System

SMTA: Standard Material Transfer Agreement

SNV: Netherlands Development Organisation

SOCC: Official Seed Control and Certification Service

SRSG: Special Representative of the United Nations Secretary-General

TRIPS: Trade-Related Aspects of Intellectual Property Rigths

AU: African Union

UEMOA: West Africa Seed Program

UNDP: United Nations Development Programme

UPOV: International Union for the Protection of New Varieties/Union Internationale pour la Protection des Obtentions Végétales

USD: USA Dollar

USAID: United States Agency for International Development

VCU: Agronomic, Technologic and Environmental Value for Cultivation and Use

WA: West Africa

WASC: West Africa Seed Committee

WIPO: World Intellectual Property Organisation

WTO: World Trade Organisation

WASP: West Africa Seed Program

WECARD: West African Counsel for Agricultural Research and Development

List of Maps, Figures and Tables

1. Introduction

*"Seed is the critical nexus where contemporary battles over the technical, social and environmental conditions of production and consumption converge and are made manifest. Who controls the seed gains a substantial control over the shape of the entire food system" (*Kloppenburg, 2010, pp. 368*).*

The pool of biodiversity from which the world's food production depends is a result of farmers breeding knowledge and practices that have been evolving since farming systems emerged (Mayet, 2015; Pistorius, 2016). Farmers have been domesticating wild species ever since (Scarcelli et al. 2006; Vodouhe et al. 2011; Mayet, 2015) and are primarily responsible for the extraordinary agro-biodiversity that exists today (Bellon, 2004; Sthapit, Subedi, Jarvis, Lamers, Rao, & Reddy, 2012; Jarvis, Hodgkin, Brown, Tuxill, Noriega, Smale, & Sthapit, 2016; Mayet, 2015). This diversity which is managed and maintained by farmers is instrumental to agro-ecosystem resilience (Lin, 2011; Halewood, 2016), food security (Halewood, 2016, Kloppenburg, 2008) and sovereignty[44] (Kloppenburg, 2010; Peschard, 2014). Since farmers are considered the stewards of this genetic diversity, their rights protection is considered of greater importance (Peschard, 2014; Andersen, 2013; Halewood, 2016).

Farmers' rights and Seed Sovereignty are overlapping concepts, although with ambiguity concerning who has sovereignty over genetic resources. There is no formal legal definition of Farmers Rights. The International Treaty Plant Genetic Resources for Food and Agriculture, in its preamble, recognizes that: the past, present and future contributions of farmers in all regions of the world in conserving, improving and making available these resources, constitute the basis of farmers' rights, as well as the right to save, use, exchange, and sell farm-saved seed and other propagating material, to participate in relevant decision-making, and in the fair and equitable sharing of benefits arising from the use of PGRFA (Andersen, 2006). While Kloppenburg (2013) defines seed sovereignty "as people's right to save, replant, breed and share seeds, and their right to participate in decision-making processes regarding rules and laws that regulate their access and use" (as cited in Wattnem, 2016, p.1). It is worth noticing that farmers' rights in the light of the ITPGRFA is contradictory with respect to the

[44] See chapter 2 for definition of food security; Food sovereignty definition: "Food sovereignty is the RIGHT of peoples, countries, and state unions to define their agricultural and food policy without the "dumping" of agricultural commodities into foreign countries. Food sovereignty organizes food production and consumption according to the needs of local communities, giving priority to production for local consumption. Food sovereignty includes the right to protect and regulate the national agricultural and livestock production and to shield the domestic market from the dumping of agricultural surpluses and low-priced imports from other countries. Landless people, peasants, and small farmers must get access to land, water, and seed as well as productive resources and adequate public services. Food sovereignty and sustainability are a higher priority than trade policies" (in Schanbacher, 2010; pp. 54)

sovereignty of plant genetic resources, because the preamble attributes an implicit sovereignty right to farmers while the sovereignty clause defines genetic resources as belonging to nation states (Andersen, 2006, Brush, 2007; Clancy & Vernooy, 2016). In this chapter, I will use both concepts interchangeably and will assume the spirit of the provisions of sovereignty as indicated in the preamble of the treaty which makes both concepts to overlap completely.

Seed security is understood in this paper as a "right-less" concept as opposed to Seed Sovereignty. Seed security "exists when men and women within the household have sufficient access to adequate quantities of good quality seed and planting materials of preferred crop varieties at all times in both good and bad cropping seasons" (FAO, 2016, p.6). While Seed sovereignty is, in the same way as food sovereignty, embedded in broader questions of social justice and the rights of farmers and indigenous communities to control their own futures and make their own decisions (Schanbacher, 2010). Despite the debates and development theories behind these concepts, both will be used in this paper in a complementary manner. Seed security will be related to the more functional aspects of seed systems notably: seed access, availability and varietal suitability while sovereignty will be an all-encompassing concept which entails a bundle of rights that goes beyond functional aspects related to seed use. It is possible to have seed security without exercising seed sovereignty.

Seed systems are the interrelated set of breeding, management, replacement and distribution of seeds that serve as a means to attain food and nutrition security, income generation and the preservation of genetic heritage (Lohr, Camacho, & Vernooy, 2015). Seed systems can also be seen as "social systems, where key practices are affected by local norms and social relationships" (McGuire, 2008, p. 217). The informal seed sector is usually defined as the total of seed production activities of farmers, in the majority composed by small-scale farmers while the formal sector refers to seed production activities led by the public and commercial sector. The informal seed sector is frequently labelled as 'local' or 'farmers' seed system(s)' (Almekinders, 2000). It is estimated that in Developing countries the farmers' seed system provides more than 80% of the total food crop seed used by farmers (Duttfield, 2007). The performance of farmers' seed systems is a result of the interactions between farmers' rights and agro-ecological systems where they operate.

Seeds are subject to a number of policies at the global and regional spheres (Galié, 2013; Atalan-Helicke & Mansfield, 2012; De Boef, Subedi, Peroni, Thijssen, & O'Keeffe, 2013). Seeds carry genetic diversity, values and information which make them subject to biodiversity and innovation policies. However, seeds are also a critical agricultural input which is subject to agricultural policies. Many of these policies translate into rights, notably community and farmers-rights over the genetic resources' and traditional knowledge. While plant variety protection policies relates to breeders' rights and national sovereignty rights over genetic resources (De Boef et al., 2013). These different sets of policies represent different and often conflicting agendas embedded in global and regional governance systems that shape farmers' rights, rules and incentives.

There are currently **three governance systems regulating seeds** at global and regional scales that interact, overlap and set policy agendas with the potential to affect farmers' rights. The first governance system is the one related to the International Treaty on Plant Genetic Resources (ITPGRFA) and the Convention on Biological Diversity (CBD). In different ways, both recognise the role that farmers play worldwide in the conservation of agricultural diversity and also their rights, namely to the protection of traditional knowledge and the right to equitably participate in sharing the benefits arising from the utilisation of plant genetic resources for food and agriculture. Particularly, the ITPGRFA addresses the farmers' rights to save, use, exchange and sell farm-saved seed. I will label the rights and rules being pushed under this governance system as the Biodiversity and Farmers' Rights Agenda (Andersen, 2006; Santilli, 2012). The second governance system concerns plant variety protection (PVP) enshrined in the International Convention for the Protection of New Varieties of Plants (UPOV Convention) which is the dominant model of protection of breeders' rights (Christinck & Tvedt, 2015) – which will be labelled as the PVP Agenda. Finally, the third governance system is the one pushing forward the West Africa Harmonized Regulatory Framework which is being implemented at the national level of ECOWAS member countries focusing particularly on quality control, certification and variety release (ECOWAS/CORAF, 2015) – the Regional Harmonization Agenda. The balance of power between these different agendas is likely to affect farmers' seed sovereignty, their ability to maintain and enhance agro-biodiversity, with direct consequences to their livelihoods.

Using as a case study the lowland agro-ecological system in the east region of Guinea Bissau, t**he objective of this chapter is to answer the following** research questions: (i) How are the international and regional seed governance regimes shaping Guinea Bissau's seed related laws, a country characterised by limited statehood?; (ii) What rules and rights emerging from these systems are affecting or likely to affect lowland female farmers' rights, with consequences on agro-biodiversity and food security? (Section 6). The research hypothesis of this paper is that the PVP (Plant Variety Protection) and Regional and Harmonization agendas will have a detrimental effect on the rights that farmers are currently enjoying concerning seeds, while the international governance system focusing on farmers' rights and biodiversity will reinforce those rights.

Looking at seed systems through its functions by framing in the dichotomy of formal and informal might be useful for diagnosis purposes. However, it is not suitable to analyse the dynamics of different but interlinked spatial, temporal and organisational scales and interactions, which shape the way seed systems function (Sumberg & Andersson, 2017). Therefore, perspectives from socio-ecological research (Berkes, Folke, & Colding, 2000, Redman, Grove, & Kuby, 2004) and social and ecological resilience frameworks (Adger, 2000; Folke, 2000) can provide interesting insights for seed system research (Sumberg & Andersson, 2017). Hence, in this chapter, I will employ a **Social-Ecological System (SES)** framework as an analytical framework to answer the research question while addressing the complexity underlying seed systems as socio-ecological systems. This framework is the most recent outgrowing of the Institutional Analysis and Development Framework proposed by Elinor Ostrom in the early 80s. Institutional Analysis and Development framework (IAD) has been used over the last 35 years as the underpinning for a focused analysis of how institutions affect human incentives, actions and outcomes. In the particular context of SES, this framework allows to examine all the core sub-systems that entail the socio-ecological lowland system in Guinea Bissau: Actors, Resource System, Resource Units and Governance System, as well as how interactions in particular situations may affect different outcomes. On the whole, this framework fits well for the research question since the germplasm contained is seed can be conceptualised as a decentralised common pool resource, while seed systems can be classified as socio-ecological systems.

The novelty of this paper is threefold.

First, there are very few case studies in the literature focusing on interactions between regulatory space that is brought by international obligations and frameworks with the domestic seed legislation and farmers rights (e.g. farmers rights and seed governance Atalan-Helicke & Mansfield, 2012; Access and Benefits Sharing Halewood, Otieno, Nkhoma, Kasasa, Wasswa, Gapusi, J., and De Jonge, 2016 and farmers rights and PVP /Sui generis regimes Srinivasan, 2003, Tripp et al., 2007). There are even fewer examples in which the analysis goes to the level of farmers' *rules in use* while at the same time providing insights on how these *rules in form*[45] might affect *rules in use* by farmers (Galié, 2013). Looking how processes of influence of the global seed governance are translating to Turkey's national seed laws Atalan-Helicke & Mansfield (2012) finds that the new UPOV based seed law established in 2006 undermines farmers' rights. Moreover, they argue that Turkey is not making use of the existing

[45] There is an important distinction in commons literature between 'rules in form' (normative instructions that can come in the form of laws or legislation that are not known about by participants or not enforced) and 'rules in use use' (normative instructions that are known and enforced and affect those interacting) (Hess & Ostrom, 2006, p. 342).

leeway to enact a *sui generis* regime that adapts its current PVP's regulations to Turkey's reality. In the context of the Access and Benefit Sharing (ABS)[46], Halewood, Otieno, Nkhoma, Kasasa, Wasswa, Gapusi and De Jonge (2016), used a participatory research approach in Rwanda, Uganda, Zimbabwe and Zambia, to investigate the status and influence of ABS, on farming communities, local climate changes and on local food crops in these countries. Amongst their research outcomes, they found that in all four countries the interests of farmers as stewards of genetic resources and traditional knowledge is not being adequately protected. Missions to collect national germplasm take place without farmers acknowledgment and are also unaware of their country's procedures and policy commitments related the obligation of access being subject to their prior informed consent on mutually agreed terms (for more details on ABS in Zimbabwe see De Jonge, Mushita, & Kasasa (2016). In terms of the influence of Plant Variety Protection laws on farmers' rights, Srinivasan (2003) uses the Indian PVP legislation to explore the feasibility of farmers' rights. He argues that *sui generis* (IPR-based farmers' rights) legal regimes entail a great administrative burden, that developing countries are unlikely to manage. Even in the event of countries being able to operationalize such regimes, these are unlikely to bring the intended economic outcomes to farming communities. Tripp, Louwaars, and Eaton (2007) based on five-country study (China, Colombia, India, Kenya, Uganda) explored the implementation of plant variety protection (PVP) regimes and examine the ability of PVP to protect breeders and farmers rights. They find that any law attempting to control seed saving by farmers is not feasible nor advisable, given the dependence of the farming communities on the informal seed systems. Furthermore, they argue that this type of legislation might be more economically favourable in settings where crops of high economic value are grown by commercial companies. Finally, they recommend that policymakers should view PVP as an instrument adapted to context and employed within an agricultural development strategy rather than a result of impositions led by industrialized countries. Galié (2013) studied the governance of seeds in Syria in the context of a participatory plan breeding program. She examined the interactions between governance regimes shaping the rights to access and control of seeds at international and national level and how these translated on the ability of women farmers to access and control the seed varieties they developed. She found that gender-equal access to seed contributes to improve household food security in small scale farming. The paper also argues that to support a gender-equal access to seed, legislation needs to explicitly protect the rights of women farmers to access and share the benefits of genetic material.

[46] The access and benefit-sharing provisions of the Convention on Biological. Diversity (CBD) are designed to ensure that the physical access to genetic resources is facilitated and that the benefits obtained from their use are shared. (in https://www.cbd.int/abs/infokit/brochure-en.pdf)

Secondly, in this chapter, I disaggregate the debate, by making a distinction between PVP (e.g. intellectual property over seeds) and non PVP rules (e.g. certification and quality control). To examine non PVP related rules is very relevant since these also have a high and maybe more realistic potential to affect farmers' rights. Most research has focused on intellectual property rights (IPR) laws that apply to seeds by privatizing germplasm, however the role that non-IPR-related seed laws related to the seed enclosure might play on farmers rights is relatively unexplored (Wattnem, 2016, Sidibé, Totin, Thompson-Hall, Traoré, Traoré, & Olabisi, 2018). Wattnem (2016) shows how and why requirements associated with certification are eroding seed sovereignty and are resulting in an additional threat to an already endangered agro-biodiversity, with a direct bearing on farmers' livelihoods. Also in the context of certification laws, a new seed law was enacted in Mali with the objective to improve farmers' access to high-quality seed as a way to promote agricultural production and enhance food security. This case study shows that despite these objectives the majority of farmers continued to rely on their traditional "unregulated" seed systems (Sidibé et al., 2018).

Lastly, yet equally important given the issues under consideration, this chapter employs and adapts the Institutional Development Framework and its most recent outgrowing - the Social-ecological System framework - to the context of seeds. This research is the first application, to my knowledge, of this approach to the common property type issues associated with seed sovereignty and seed security. Examples of similar analysis using the SES framework are the study of small-scale fisheries in Baja California Sur, Mexico, to identify distinct socio-ecological systems (SES) regions to test critical aspects of coupled SESs (Leslie, Basurto, Nenadovic, Sievanen, Cavanaugh, Cota-Nieto, & Nagavarapu, 2015) and in the context of lobster fisheries in the Southern California Spiny Lobster Fishery (SCSLF) (Partelow & Boda, 2015). The analysis carried out in these two papers served as assessment tools of the different systems, as well to propose management approaches towards socio-ecological ecosystems sustainability. However, this chapter is the first to apply the framework to the agricultural sector in general and the seed sector in particular, bringing the SES framework into the global governance systems and debates around seeds.

I used the Socio-ecological framework to examine the following interactions among the socio-ecologic core sub-systems: (i) Interactions between different Governance Systems: (a) International Treaty on Plant Genetic Resources for Food and Agriculture and Convention on Biological Diversity, (b) International Union for the Protection of New Varieties of Plants, (c) Regional Harmonization and (d) Governance system in use. (Section 6.1, 6.2, 6.3, 6.4); (ii) Interactions between Governance Systems and Actors, particularly in the context of laws and regulations affecting specific property rights held by individual or collective actors and local knowledge over resource units: e.g. seeds. (Section 6.1, 6.2, 6.3, 6.4) and (iii) Interactions between Governance System and Resource System, namely related to the fit between scales of the resource (e.g. lowland production system) and governance systems. (6.4). This chapter will then examine how these interactions impact farmers' rights, which can be thought as an equity measure and a measure of social performance in the light of the SES framework terminology. It is assumed that farmers' rights are a necessary condition to the conservation of agro-biodiversity *in situ*.

Using this framework this chapter finds that the international and regional seed governance regimes are not being translated into Guinea Bissau's seed related laws at least in a formal manner. Despite of the preparation of legal draft documents (e.g. seed law; certification and quality control regulations), the persistent state of political instability undermines state capabilities of developing, promulgating and enforcing these legal instruments. It was found that international regimes, such as Convention of Biological Diversity (CBD) and International Treaty Plant genetic resources for food and agriculture (ITPGRFA), that are designed to reinforce and ensure farmers' rights, have virtually no expression in Guinea Bissau nor have been translated into any relevant activities or legal instruments. On the Plant Variety Protection (Bangui Agreement) and Regional Harmonization (ECOWAS) governance regimes, in line with the vast literature these were found to have rules that, if translated to domestic law and enforced, were likely to undermine the seed sovereignty currently being experienced by Guinea Bissauan lowland female farmers. Nonetheless, it was shown that in this particular context there are little incentives and capacity from the Guinea Bissauan state to move forward and enforce a *sui generis* regime that could balance the *de jure* laws more in line with *de jure*, in favour of farmers' rights'.

On the whole, this study suggests that the most cost-effective way to ensure farmers' rights, is to invest on reinforcing the polycentric system in use, in a sensitive way, understanding the cultural, taxonomic and legal complexities involved. Since farmers rights' are considered as a necessary but not sufficient condition to ensure food sovereignty and biodiversity, it is recommended that *de facto* policies, namely the ones introduced by development projects, should focus on creating incentives towards collective action around crop diversity and ensuring food sovereignty to lowland community in Guinea Bissau. The reinforcement of the ability of farmers to exercise agency within the existing polycentric[47] system seems to be the only way forward to lowland farmers' seed sovereignty in Guinea Bissau.

[47] 'Polycentric' connotes many centers of decision making that are formally independent of each other. Whether they actually function independently, or instead constitute an interdependent system of relations, is an

Section 2 provides an overview of the study area and data collection, as well as on the conceptual, theoretical and analytical framework. Section 3 characterises the overall social, political and economic setting as well as provides a historical perspective of rice production in Guinea Bissau and on the evolution of the seed research system. Section 4 examines the four subsystems underlying the SES framework: Resource System, Resource Units, Governance System and Actors and their interrelations. Section 5 looks at the interactions between and across the three formal governance systems: (i) Biodiversity and Farmer's Rights, (ii) PVP and (ii) Regional Harmonization, and how these are affecting farmers´ rights. Section 5 concludes and presents policy implications of these findings, through risk and opportunity analysis for lowland female farmers in Guinea Bissau.

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empirical question in particular cases. To the extent that they take each other into account in competitive relationships, enter into various contractual and cooperative undertakings or have recourse to central mechanisms to resolve conflicts, the various political jurisdictions in a metropolitan area may function in a coherent manner with consistent and predictable patterns of interacting behavior. To the extent that this is so, they may be said to function as a 'system'. (V. Ostrom, Tiebout, & Warren, 1961, pp. 831–32)

2. Data Collection and Analysis Framework

2.1. Study Area and Data Collection

The data used in this chapter was collected using the following methods. First, quantitative data was collected by a survey of farmers in the Contuboel sector; this survey focused on three main aspects: i) household and farmer's demographic and socio-economic characteristics, ii) farm and agricultural production and iii) seed security characterisation. A total of 351 households were interviewed between February and March 2015, immediately after the harvest period and before the sowing period of the following rainy season (see Chapter 1 for details on data collection and sampling design). Secondly, with the twofold purpose of preparing the survey questionnaire and collecting qualitative data covering the seed system, seed security and sovereignty issues: (i) 5 semi-structured interviews were conducted with seed related organisations working at the regional level, (ii) 6 focus group meetings implemented with both female and male farmers and 16 individual interviews (8 female and 8 male farmers) aiming at having disaggregated information on upland and lowland productions systems and (iii) 5 semi-structured interviews with key informants, (iv) document analysis and literature. The data collected above can be organised along the different levels of the analysis and the different topics that will be covered in this chapter, as follow:

- Meta-constitutional, Constitutional and Collective Level (Government and other Formal Institutions): Literature review of reports of different institutions and papers discussing relations between institutions and institutional information from websites;
- Operational Level and Collective Level (Farmers, NGOs and Government Institutions):
    - Focus groups on Seed Systems, Seed Security and Seed Sovereignty (*Rules in use*)
    - Semi-structure Interviews on Seed Systems, Seed Security, Seed Sovereignty and History or past experiences of Organisations (*Rules in use*): Regional Directorate of Agriculture, National Research Agricultural Research Institute INPA- Contuboel Research Center, Guiarroz, Proagri, APALCOFE)
    - Specific Interviews on Seed Sovereignty Topic with Key Informants working directly with resource users at the operational level (TESE, Guiarroz, APALCOFE, Agromultipliers Association)

Refer to **Appendix V** on the list of interviewees, location and dates of the interviews and for further details on the Study Area in Chapter 1.

2.2. Conceptual and Theoretical Framework

Most seed systems analyses focus on their functions – such as seed availability, appropriateness of variety, access, quality and resilience. Following this view of the seed system, many approaches for analysing seed systems have been employed in research (for example, Hirpa, Meuwissen, Tesfaye, Lommen, Lansink, Tsegaye, & Struik, 2010; Jones, 2013, Remington, Maroko, Omanga, & Charles, 2002, Weltzien & vom Brocke, 2001). More recently, the seed security conceptual framework developed by FAO (2015) provided an improved basis for assessing and analysing seed security and developing appropriate actions to be taken. A relatively new method of analysis following this framework, the Seed System Security Assessments (Byrne, March, McGuire, Meissner, & Sperling, 2013, Sperling, 2008) also looks at the functioning of all the seed systems farmers use: 'formal channels' and 'informal channels' while looking in detail at seed security dimensions (See Chapter 2 for details on seed security).

Conceptualising seed systems according to their functions although useful at a more operational level does not allow for more complex analysis. Framing seed systems in the dichotomy formal and informal do not enable an analysis of the dynamics of different but interlinked spatial, temporal and organisational scales and interactions underlying seed systems. As proposed by Westengen (Sumberg & Andersson, 2017) perspectives from socio-ecological research (Berkes et al, 2000; Redmen et al, 2004) and social and ecological resilience frameworks (Adger, 2000; Folke, 2000) can provide interesting insights for seed system research. Hence, this paper follows Institutional Analysis and Development framework that has been widely used in the analysis of collective action problems that involve the governance of commons (Ostrom, 2009; McGinnis & Ostrom, 2014).

Seeds are complex goods, having characteristics of private, public, club and common pool resources. Plant seed or animals have the physical characteristics of a private good. However the germplasm contained within a seed has the public good attribute of being "non-rival" (Di Falco & Perrings, 2005; Heisey et al., 1997). Seeds can also be conceptualised as a common pool resource. Farmer-to-farmer seed exchange forms dynamic networks where, through social relations, interdependence and reciprocity rules, farmers have access to other farmers' seed stock. Also, farmers generate and participate in organised germplasm exchange systems, such as seed fairs and community seed banks. Both informal and more formal stocks of seed form a decentralized and changing pool of germplasm (Halewood, Noriega, & Louafi, 2012; Halewood, 2013; Andersen, 2006).

Nonetheless, without the adequate management of a large gene pool, informal crop improvement and formal breeding will lose all of their basic inputs. On the whole, genetic diversity is a resource that is renewable and exhaustible at the same time (Lohr et al., 2015). As pointed by Halewood (2013) there is a high level of conceptual confusion regarding the status of Plant Genetic Resources for Food and Agriculture, namely seeds, a vis-à-vis the classic goods quadrant frequently mentioned in commons-related literature (**see Table 1**).

Table 1. Subsets of Seeds characterised as different goods

		Subtractability of Use	
		High	**Low**
Difficulty of Excluding Potential beneficiaries	**High**	**Common-pool resources:** ▪ Seed 'ideas' embedded in threatened situ populations ▪ Unique samples/units in threatened *ex situ* collections	**Public Goods:** ▪ Seed 'ideas' embedded in non-threatened *in situ* populations ▪ *Ex situ* collections hosted by CGIAR centres and many European countries (global public goods) ▪ Collections in national genebanks (national public goods) ▪ *In situ* on lands managed and controlled by the national government (In the absence of farmer management) ▪ Seed 'ideas' embedded in threatened situ populations ▪ PVP protected seeds (for purposes of research, breeding, private, non-commercial use
	Low	**Private goods:** ▪ Seed Artifact as a private good: seeds as an output and input of agricultural production owned by farmers under customary practice ▪ Seeds Ideas as a private good: that are subject to strong national ABS laws including potentially *ex situ* and *in situ* Seeds held by provincial governments, private universities, companies, civil society ▪ Organisations, and farmers, and in the wild (except those on public lands) ▪ Patent or PVP protected Seeds ▪ Hybrid parental lines, hybrid seed (that are not shared publicly)	**Toll or club goods:** ▪ Patent pools ▪ Seeds subject to facilitated access in research consortia ▪ Seeds subject to humanitarian use licenses

Source: Adapted from Ostrom (2010) and Halewood (2013)

There is also frequent confusion between the Nature of a Good and the Property Regime. To this effect, before moving to property rights systems, it is worth clarifying the differences between Rules, Rights, and Property Systems.

“The terms "rights" and "rules" are frequently used interchangeably in referring to uses made of natural resources. Clarity in analysis is enhanced by recognizing that "rights" are the product of "rules" and thus not equivalent to rules. "Rights" refer to particular actions that are authorized "Rules" refer to the prescriptions that create authorizations. A property right is the authority to undertake particular actions related to a specific domain (Commons 1968). For every right an individual holds, rules exist that authorize or require particular actions in exercising that property right”… “To possess a right implies that someone else has a commensurate duty to observe this right (ibid.). Thus rules specify both rights and duties.” (Schlager & Ostrom, 1992)

The conventional typologies of property rights systems are four as presented in the Table 2 (Cole, 2012)

Table 2. Conventional Typology of Property Systems

State/public property The state or its agencies have the right to determine rules of access and use, but a duty (at least in theory) to manage publicly owned resources for the public welfare. Individual members of the public do not necessarily have a right of access or use, but they have a duty to observe access and use rules promulgated by the controlling/managing agency.
Private property Owners have the exclusive right to undertake socially acceptable uses to the exclusion of nonowners, and they have a duty to refrain from socially unacceptable uses. Nonowners have a duty to refrain from preventing own ers’ socially acceptable uses, but they have the right to prevent or be compensated for socially unacceptable uses.
Common property Each member of the ownership group has the right to access and use group- owned resources in accordance with access and use rules established collectively by the group, and a duty not to violate access and use rules. Each member also has the right to exclude non-members of the ownership group, but no right to exclude other members of the ownership group. Non-members of the ownership group have a duty not to access and use the resource except in accordance with rules adopted collectively by the ownership group.
Nonproperty/open access No individual has a duty to refrain from accessing and using a resource. No individual or group has the right to prevent any other individual or group from accessing and using the resource as they choose.

Source: Cole (2012)

Schlager and Ostrom (1992) conceptualised property-rights systems as containing bundles of rights rather than a single right. While carrying a meta-analysis of field cases they have identified five property rights that individuals using a common-pool resource might cumulatively have: (1) Access – the right to enter a specified property,4 (2) Withdrawal – the right to harvest specific products from a resource, (3) Management – the right to transform the resource and regulate internal use patterns, (4) Exclusion – the right to decide who will have access, withdrawal, or management rights, and (5) Alienation – the right to lease or sell any of the other four rights. Conceiving of property-rights bundles is now widely accepted by scholars who have studied diverse property-rights systems around the world (Brunckhorst 2000; Degnbol and McCay 2007; Paavola and Adger 2005; Trawick 2001; J. Wilson et al. 1994; as cited in Ostrom, 2009). In the particular context of the new commons framework, these rights were adapted to better fit the analysis of knowledge as a common good (Hess & Ostrom, 2007). The new commons framework will be the conceptual framework employed in this chapter when analysing the property regimes over seeds and germplasm.

Despite seeds being frequently labelled as global commons, there is no explicit reference in ITPGRFA. Seeds do not fit easily in the traditional commons scholarship focused on cases studies of collective management, which are characterized by a small number of users, of rivalrous, non-excludible natural resources, concentrated in delimited geographic areas, that were not exclusively subject to market or government control. However, seeds fit in the 'New commons' literature which has expanded its scope to consider non-rivalrous goods. This is corroborated by Halewood (2013) when stating that FAO's Global System and the Treaty's multilateral system of access and benefit-sharing in particular, conform in many respects to what is referred to, in relevant literature, as a 'new commons' (e.g. Gulati 2001; Falcon & Fowler 2002; Halewood, Andrieux, Crisson, & Gapusi, 2013). Seeds can be thought of in the same way as knowledge since they are developed, maintained and used by potentially limitless numbers of people worldwide (Hess & Ostrom, 2006, 2007; Madison, Frischmann, & Strandburg, 2010). Just like information seeds have "complex tangible and intangible attributes: fuzzy boundaries, a diverse community of users on local, regional, national, and international levels and multiple layers of rule-making institutions." (Hess & Ostrom, 2003, p.132). Seeds systems are a decentralized and changing pool of commons.

Therefore this paper conceptualizes seeds as being part of the 'new commons' within the Institutional Analysis and Development framework (IAD) framework. It will specifically examine farmers' rights pertaining "seed as an artifact" the physical and tangible component of seeds and "seed as an idea" the non-physical and untanginble component of seeds (See section 4 Resource System and Units for more details on seed as ideas and artifact). Specifically, the approach follows a more recent outgrowth of the new common literature — the social-ecological system (SES) framework – using some insights of the information/knowledge as commons adapted the IAD framework. This framework and approach, to examine the issues of seed sovereignty in a context of State Fragility, using the lowland rice sector and Guinea Bissau as case study.

2.3. Social-Ecological Systems Framework

This chapter follows Elinor's Ostrom "General Framework for Analysing Sustainability of Social-Ecological Systems" (2009). This framework fits well for the research question since the germplasm contained in seed can be conceptualized as a decentralized common pool resource and also seed systems can be classified as socio-ecological systems. Moreover, the objective of employing the SES framework to answer the research question stems from the fact includes all the core elements that allow a comprehensive institutional analysis of the governance systems and their actors, their strengths and weaknesses, and the way in which they affect the farmers' rights to seed, with implications to food security and the conservation of agro-biodiversity.

This framework is a multilevel, nested framework composed of four first-level core subsystems of a Socio-ecological System that affect each other as well as linked social, economic, and political settings and related ecosystems. As presented below in **Figure 1** the subsystems are; (i) resource systems (e.g. the seed system); (ii) resource units (e.g. seed); (iii) governance systems (e.g. the government and other organisations that manage plant genetic resources particularly seeds, the specific rules related to the use of the system and how these rules are made); and (iv) actors (e.g., individuals who use the germplasm in diverse ways for sustenance, recreation, or commercial purposes). Each core subsystem is made up of multiple second-level variables (e.g., size of a resource system, mobility of a resource unit, level of governance, users' knowledge of the resource system), which can be further composed of deeper-level variables (Ostrom, 2009; McGinnis & Ostrom, 2014). Second-level variables under first-level core subsystems are presented in Annex 2.

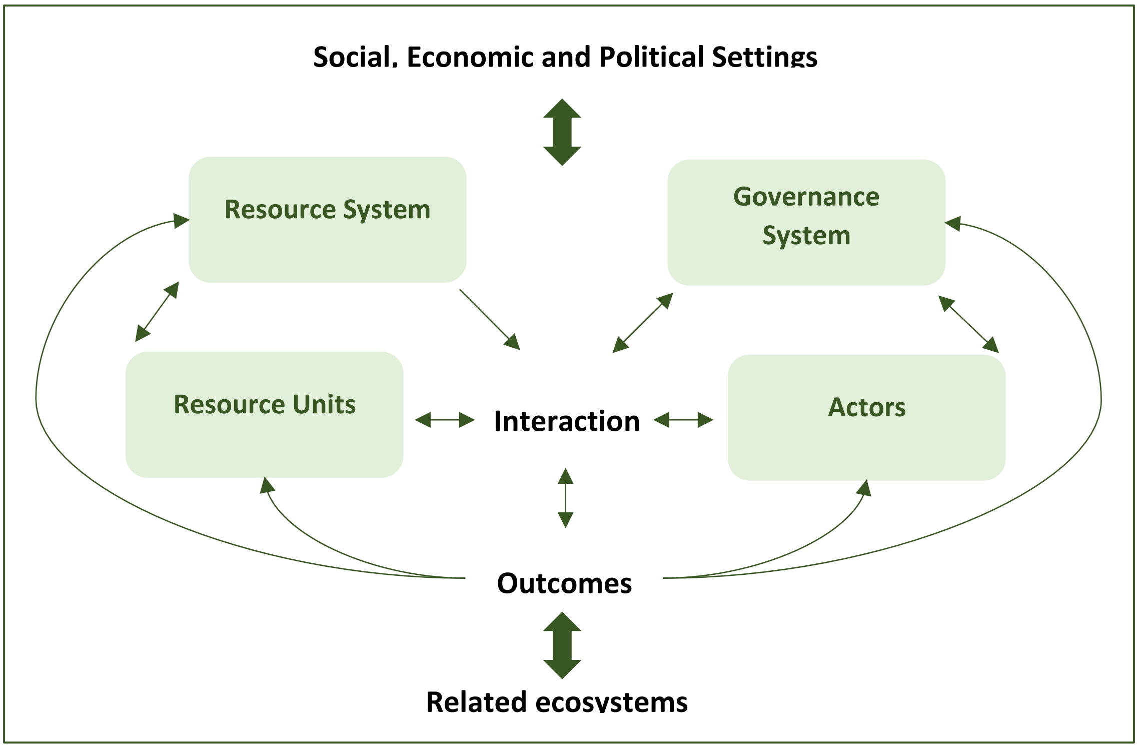

Figure 1. The core subsystems[48] in a framework for analysing social-ecological systems

(Source: adapted from Ostrom, 2009)

The **Interactions** that will be examined in this paper will be as follows:

- Governance System <> Governance System Interaction. Interactions between different governance systems: (i) International Treaty on Plant Genetic Resources for Food and Agriculture and Convention on Biological Diversity, (ii) International Union for the Protection of New Varieties of Plants, (iii) Regional Harmonization, (iv) Governance system in use. (Section 6.1, 6.2, 6.3, 6.4)
- Governance Systems <> Actors Interaction. Interaction in the context of laws and regulations affecting specific property rights held by individual or collective actors and local knowledge over resource units: e.g. seeds. (Section 6.1, 6.2, 6.3, 6.4)
- Governance System <> Resource System Interaction. Interactions related to the fit between scales of resource (e.g. lowland production system) and governance systems. (6.4)

(For more details on types of Interactions between first-tier components see McGinnis, 2010)

[48] Also labelled as first tier variables

This analysis in undertaken in the context of state fragility. With respect to **Outcomes** this paper will be looking on how these interactions impact **farmers' rights**, which can be thought as an equity measure and a measure of social performance. It is assumed that farmers' rights are a pre-condition to the conservation of agro-biodiversity *in situ*.

The SES framework will be the key framework employed in this chapter although with small conceptual departures that are thought to better fit the research questions at hands. Seeds do not fit in the traditional commons scholarship focused on cases studies of collective management, by a small number of users, of rivalrous, non-excludible natural resources, concentrated in delimited geographic areas. There are some parallels between seed as commons and knowledge as commons, in the same way as knowledge seed can be broken down between the idea (i.e. the nontangible, informational component) and artifact (i.e. the tangible, physical component). Therefore in the SES framework, some **insights of the "new commons"** literature will be included. In IAD's framework there is strong focus on *rules in use* (e.g. customary practices and institutions shaping the way farmers exchange seeds) as opposed to *rules in form (e.g.* seed laws*)*, however evidence shows that the *rules in form* in the context Guinea Bissau, which appear as *rules in use* elsewhere, might be undermining farmers' rights. As pointed by Cole (2014) the IAD fails to **explore the complex relations between formal legal rules, that is the "rules-in-form and "rules-in-use"**. Finally, to support the analysis of section 6 **on interaction and outcomes** I employ a **graphic representation of adaptive governance systems** (e.g. Andersson & Ostrom, 2008; Folke, Hahn, Olsson, & Norberg, 2005; Berkes, 2007). The implementation of this approach admits graphical explanations based on qualitative data to provide a picture of the actors, links existence and strength to provide insights of the dynamics of different governance structures that interplay with farmers' rights and the socio-ecological system. Hence, it should not be interpreted as a network analysis, but rather a graphic representation based on data collected from an extensive analysis of documents or literature review as well as from interviews that took place with collective and operational level actors. These diagrams also have the objective to represent the second tier variables under the Governance system "network structure" as proposed by McGinnis and Ostrom (2014) (see **Appendix II**). Overall the objective is to characterize the networks' structure by showing the connections among the rule-making organisations and the population subject to these rules.

With respect to the more specific variables, which aim to characterise each of the governance sub-systems, it is important to highlight the following. The first tier variables or core subsystems (e.g. Resource Units, Resource System and so forth) can be broken down into second-tier variables

(McGinnis & Ostrom, 2014). The majority of these variables are discussed in this paper. However, some were not included, due to data unavailability or due to being irrelevant to the issue in question which is farmers' rights (for details on second-tier variables see in Appendix II).

The analysis proceeds as follows:

- Social, Economic and Political Settings>Section 3
- Resource System and Units> Section 4
- Governance System> Section 5
- Actors> Section 5, since Actors and Rulemaking organisations, overlap to a great extent, given the multi-level and multi-scale interaction analysis of this paper
- Interactions and Outcomes> Section 6

The following section will provide the Social, Economic and Political Settings, that describes the background and the exogenous aspects that can influence the other core sub-systems (e.g. Resource systems and units) as well as the interactions (I) among them and outcomes (O).

3. State Fragility, Rural Society and Seed Systems

This section will focus on **Social, Economic, and Political settings (S)** variables, which are external the Social/ecological system (n.b. highlighted in dark orange in the scheme below), though providing the context and background to the socio-ecological system under analysis. In particular, this section will describe the following second tier variables: S1 – Economic development, S2 – Demographic trends and S3 – Political stability that affect the socio-ecological system. (See Appendix 2 First and Second-tier variables of a social-ecological system for details on the second tier variables).

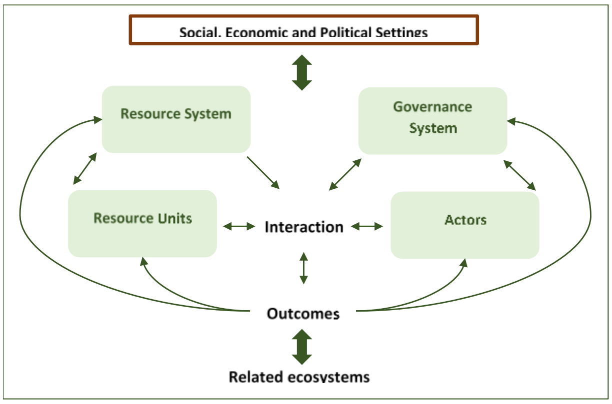

Figure 2. Social-ecological system: Social, Economic, and Political settings (S)

3.1. Current economic situation and Demographic trends

Guinea-Bissau is one of the world's poorest and most fragile countries. In 2017 Guinea Bissau had a GDP of 625.9 USD per capita[49] and ranked 178th the out of 187 countries on the 2016 Human Development Index (UNDP). With a population of 1.8 Million, 69.4 per cent (1.2 million people) live below the poverty line while one-third of this population (33.1) living in extremely poor conditions (World Bank, 2017). The limited economic growth had no identifiable or sustained poverty reducing benefits. The fast-growing working-age population also poses a threat to development prospects as new jobseekers put pressure on the labour market (World Bank, 2017). With the current underemployment and the lack of jobs outside the cashew sector, it is likely that household income will decline further as younger generations contribute little or no additional income. Despite this bleak picture Guinea Bissau is rich in natural resources, such as fisheries, forestry and agriculture and biodiversity (World Bank, 2017).

[49] http://pubdocs.worldbank.org/en/618081492207279284/data-gnb.pdf

Since independence Guinea Bissau has experienced continuous political and institutional fragility. With four successful coups and 16 attempted, plotted, or alleged together with very high government turnover where every year, between 1999 and 2009, Guinea Bissau experienced a change of government. During the year that followed the return to constitutional order in 2014, Guinea-Bissau experienced positive momentum, but since then the government has changed another four times. Despite the delicate political context, gross domestic product (GDP) grew by an estimated 4.9% in 2016, driven mostly by a good agricultural season (AfDB, OECD & UNDP, 2017).

Fragility in Guinea-Bissau is rooted in its historical past and manifests in a disconnection between state and society. Forrest (2003) argues that the "rural civil society—characterized by rural-based social institutions that, having developed over the course of centuries, have become entrenched in the lifeblood of local society—can prove an enduring impediment to state building, while, at the same time, making possible a substantial degree of local-level autonomy and regional self-empowerment" (Forrest, 2003, p. 3). Therefore, weak states are most likely to occur where social structures are represented by "weblike" complexity, of a tenacious and resilient nature, with high levels of political fragmentation and pluralism, resulting in the capacity of "social organisations" to function separately from state institutions (Forrest, 2003). The vacuum left by the Bissau Guinean state, particularly in rural regions, leaves the provision of the most basic services to rural societies in the hands of traditional and informal authorities and organisations (Barry, 2007).

State fragility is also a result of the powerful military forces in place in Guinea Bissau. Strong indigenous armies are a result of a long-standing set of experiences of success at warfare during pre-colonial times. These capabilities, together with a weakly endowed colonial bureaucratic infrastructure resulted in the long-lasting and effective anti-colonial war-efforts led by Guinea Bissau (Forrest, 2003). This politico-military elite that emerged from these precolonial indigenous armies gained a strong historical legitimacy for Guinean Bissau people over decades due to their decisive role in the liberation war. Nonetheless, this elite has become increasingly detached from the population, concerning both democratic legitimation and government revenue (Kohnert, 2010). This political-military elite beyond competing for rents (Barry, 2007), are thought to have a critical role in drug trafficking with high ranking officers of the army and senior government officials being reported involved in the drug trafficking activities. On top of being a fragile state, Guinea-Bissau has been labelled as a narco-state becoming one of the main cocaine trade hubs in West Africa region with the apparent consent of and in close cooperation with parts of the army and high ranking politicians (Kohnert, 2010; World Bank, 2017).

Rent seeking is also pervasive and further contributes to state fragility. Guinea's power elite has been increasingly relying on sovereign rents (Kohnert, 2010; World Bank, 2017) from aid and illicit trade such as fish, drugs and weapons, over the past few decades (Schiefer, 2002 as cited in Kohnert, 2010; Chabal & Green, 2016; World Bank, 2017). Public administration characterised by a large bureaucracy, with an overrepresentation of the military, is unable to control and to oversee rent-seeking behaviour in the public sector. A great deal of public resources are redirected towards private gain (World Bank, 2017). Guinea-Bissau is ranked 168 out of 176 countries surveyed in Transparency International's 2016 Corruption Perceptions Index (CPI) with a score of 16 out of 100 (Transparency International, 2016).

3.2. History of Rice Production and National Agricultural Research System

Rice cultivation began with the cultivation of mangrove rice in the Mansoa River Valley in the Northern agro-ecological zone in the **pre-colonial era** more than 500 years ago when young people supplied the majority of the labour force, and there was abundant rainfall and high soil fertility. Traditional Balantas farmers gained land of the sea, desalinated these lands through dykes construction. At early stages of colonization and under these agro-ecological conditions, the mangrove rice production system, at the time, reached its maximum productivity, obtaining surplus production (Djata, Mané, & Indi, 2003). During **early stages of the colonial era** the negative impact of the shift to peanut production, and the pacification wars in the north resulted in a decline of production in the period between 1890 and 1926, a period characterised by severe food shortages, with the need to import 4.000-5.000 tonnes of milled rice. In the following period many of these farmers, who were forced to migrate to the southern regions of the country during the pacification wars, become more efficient in rice production in the new agro-ecological areas of the south, which were well adapted to rice production, and further enhanced their expertise. Between 1930 and 1960 Guinea-Bissau was self-sufficient in rice being able to export the surplus (Djata et al., 2003). During **liberation war (1955-1960) and the ensuing civil war** (1963-1973), rice production declined again due to the effects of the sustained conflict: infra-structure destruction, erosion of social norms, social unrest, terror and displacement of people. Urban centres which were under the control of colonialists were forced to import rice. Liberated areas controlled by the PAIGC producers were forced to develop subsistence rice cultivation in less productive rain-fed areas (Mpam-pam). The **post-colonial period** was the period marked by the relaunch of agricultural production between 1973 and 1987. The newly liberated state agricultural policy established measures related to rice production, notably an extensive restoration of marine hydromorphic soils, construction of barriers and anti-salt dams for further rice cultivation. Research projects resulted in the construction of 48 anti-salt dams that allowed to protect more than 100 000 ha of land. It was also during this period that the government with the support of international agencies encouraged the production of rice in the valleys (*basfond*), areas predominantly worked by women. Several projects with external support were implemented until 1995 and the areas covered were estimated at 39 369 ha. Upland rice production was then discouraged (INEC, 2001).

The large potential of lowland rice production has been increasingly recognized since then. Lowland agro-ecological systems have an agricultural potential of 200,000 ha while only 92,998 are currently being cultivated. Both Terra Ranka, the latest government development strategy, and the National Agricultural Letter place rice production (including seed) on the lowland agro-ecological areas at the top of the list of priorities for food security.

The **evolution of the seed sector** in Africa was stimulated by changes in research and development approaches. Three major phases of this evolution can be identified. First, the Pre-independence to 1980s, when the provision of seeds was state-managed and crop varieties mainly came from the national research institutions and the CGIAR centres. Then from 1980 to 1990s, perido when the seed sector was liberalized and privatized. Finally, from 1990 to present, a period characterised by the increased role of the private sector in both the formal and informal seed sector, including the involvement of multi-national companies, farmer groups and cooperatives (CORAF/WECARD, 2014).

However, Guinea Bissau's formal seed sector development had its own idiosyncratic path. Although there is now specific reference to seeds, some research suggests (Galli & Jones, 1987; Galli, 1990) that before independence, in line with other Portuguese colonies, inputs directed to more commercial farms such as "Pontas"[50] were provided through Casa Gouveia, a network of stores which was replaced by PAIGC after independence by the state-run parastatal Armazéns do Povo. On the other hand Smallholders, who were operating under the customary tenure system were, mainly supplied through farmers' traditional seed systems.

After independence with the First Economic Development Plan (1983-1986) and the Economic Stabilization Program extended to 1989, priority was given to agriculture. In this context, it was necessary to develop rice seed cultivation through the organisation of agricultural development around the production of selected seeds adapted to local conditions, with high yields, resistance to insects and diseases, and adapted to climatic hazards. The objective, in this case, was to reduce losses and increase yields and production. Several projects were implemented in pursuit of these objectives.

[50] commercial farms which land was provided by the state as concession

Examples of these projects, are two large projects promoted by FAO and UNPD[51] which had the following objectives:

(i) To help the government acquire the technical and institutional means to achieve self-sufficiency in quality seeds (rice and other crops) and thus succeed in the eliminating seed imports;

(ii) Set up adequate infrastructures and equipment, to carry out the training of managers, to form groups of producers who will be in charge of producing R1 seeds (first reproduction), thus having a robust seed sector at the national level and;

(iii) Promote the establishment of a solid rice research program (with experimental networks and field demonstration fields).

The key activities of these projects were: (i) producing sufficient quantities of improved seeds of the main food crops (e.g. rice millet sorghum, cowpeas); (ii) turn Contuboel and Caboxanque centres into national seed experimentation and multiplication centres; (iii) strengthen these centres's capacity for agricultural research in order to boost the country's agricultural development; and, (iv) establish an effective and efficient national seed service. Along 14 years of implementation these projects achieved the following outcomes. Firstly, they create a network of 510 seed multipliers including 360 in Contuboel and 150 in Caboxanque. Secondly, the establishment of seed treatment and conditioning facilities, and equipment. Finally, they have increased the yields of rice from below 1.5 ton/ha to 4 ton/ha *in station* and to 2.5 t/ha i*n field* and the production of good quality rice seeds from 70.3 tons, in 1980 to 425.6 tons, in 1985 (MDRA, 2015; EU, 2015).

According to Dr. Simão Gomes, current President of INPA, after 1989 the seed production program entered the most critical phase, a period in which the germplasm of most of the varieties began to degenerate (EU, 2015). Despite the promising results of the above-mentioned projects that boosted the seed sector, at present (2018) there are only 60 INPA agro-multipliers farmers[52] (20 in Caboxanque, 20 in Carantaba, and 20 in Contuboel). Consequently, there is a low capacity for rice seed production at the national level and in rural areas in particular and an absence of seed agro-multipliers at the level of other crops such as dry cereals, vegetables and legumes (MDRA, 2015)

During the 1999-2000 agricultural year, FAO signed with INPA a contract to produce 70 tons of quality seeds, 30 tons of mangrove rice and 40 tons of rice from *basfonds* which resulted in the amelioration

[51] UNDP/FAO/GBS/75/039 (rice seed multiplication, activities, 1975-80) and UNDP/FAO/GBS/81/009 project (experimentation and multiplication of rice seeds and other crops (dry cereals, pulses, activities 81-85)
[52] Farmers dedicated two produce seed particularly

on the quality seed production capacity. During the 2010-2011, a FAO project, funded by the EU's "Food Facility" program with the objective of reducing the weight of food expenditure on households, undertook the following activities: (i) purchased 60 tonnes of INPA seeds, boosting INPA's capacity in seed production; (ii) trained 40 multipliers and 20 technicians from INPA and APRODEL (Guinean NGO), APALCOF (Community Based Association), and Instituto Marques Vale Flôr (International NGO) (EU, 2015).

Also, the Africa Rice Centre, a Consultative Group on International Agricultural Research (CGIAR) centre[53] dedicated to rice research, has contributed to the rice seed sector development in Guinea Bissau. Given the political instability, unlike other **Africa Rice Centre** member states, Guinea Bissau has not been able to participate consistently in any of the centre's dissemination programs. There are records of Guinea Bissau receiving Africa Rice improved varieties in 2000, 2005 (Nerica Module) and also few times between 2010 and 2014 (see Annex 3 Local Seed Varieties and Improved Varieties). However, INPA's lack of human and financial resources has curtailed a continuous and consistent collaboration between Guinea Bissau's national agricultural research system and Africa Rice Centre for the multiplication and diffusion of modern rice varieties.

Despite the continuous constraints, since 2010 the Contuboel and Caboxanque research centres are conducting some research activities, in the context of the EU Facility project promoted by FAO with the support of the Africa Rice Centre. Particularly in Contuboel research centres, through a Participatory Varietal Selection[54] approach, 34 varieties were tested of which 31 were provided by the Africa Rice Centre (NERICA and Sahel) and three controlled local varieties. Along with the PVS process 20 rice farmers visited the station field in four phases of the production cycle to evaluate the different varieties: i) flowering, ii) maturation, iii) pre-harvest and iv) harvest. In each stage of the evaluation, each farmer placed one stick on its preferred variety, by the end of the evaluation process, the five varieties with more sticks were the ones selected for multiplication. Therefore at the end of the PVS process farmers chose the following lowland varieties: Nerica L-14, Nerica L-19, Nerica S-19, Sahel 222 and Sahel 317 as the most adapted to the station conditions. More recently, in 2013 the Africa Rice

[53] Consultative Group on International Agricultural Research Research Centers are independent, non-profit research organisations, conducting innovative research

[54] "Participatory varietal selection (PVS) is the selection by farmers on their own fields of finished or near-finished products from plant breeding programmes. These include released cultivars, varieties in advanced stages of testing, and well characterised material such as advanced non-segregating lines in inbreeding crops, or advanced populations in outbreeding crop" in Farmer Participatory Approaches for Varietal Improvement A. Joshi and J.R. Witcombe

Centre and the Ministry of Agriculture initiated a more formal collaboration with a well-defined program to be implemented in the Bafatá region. In 2014, the Africa Rice Center and Ministry of Agriculture were jointly selected to be an Africa Rice Centre (AfRC) "hub"[55] in Guinea Bissau, with the program placed in Bafata and Contuboel rice growing sectors. Some of the activities of the program and the hub will focus on capacity building, baseline survey implementation, multiplication of improved varieties and the dissemination of 60 tons of improved rice varieties (25 kg per household).

The current Africa Rice support efforts contributed to a large production of improved varieties in the Contuboel INPA's centre. In 2013 dry season INPA centre at Contuboel planted these varieties for multiplication in 12 ha of irrigated lowland with a production of 45 tons of rice seeds. This production of seeds was distributed in the following manner: 6 tons remained in the centre for multiplication; 18 tons were sold to the Government by INPA headquarters and 18 tons given for free to the Government to be distributed by different Regional Directorates of Agriculture in the country. According to the centre administrator, Bafatá regional's directorate was the one who received most of the seeds they produced and that this seed should be distributed to the most insecure villages. In 2013 rainy season 10 ha of irrigated lowland fields were planted resulting in a production of 22 tons of seeds. Half of this production was sold to the West African Monetary and Economic Union (UEMOA), and the remaining 11 tons were saved for the Africa Rice Centre diffusion program. For the 2014 dry season, INPA's Contuboel centre expected the production of 49 tons of improved varieties seeds which, when added to the previous 11 tons, will achieve the target amount for the Africa Rice program (60 tons).

The Africa Rice guidelines for the dissemination program are for the Regional Directorate of Agriculture to distribute 25 kg per family in the Rice Hub. Overall, the production of improved seeds was considered very weak in the agricultural year 2013/2014. There were 252 seed multipliers, 131.6 hectares of irrigated land in the Geba river valley, and the production of 574.1 tons, with the capacity to provide producers with seeds of more or less good quality for 9 568 ha or 4% of the total cultivated area estimated as 225,892 ha in 2013/2014. A survey held under EU-AINDA program has shown that the centres have sufficient land, surface water available to expand and to increase their production through their trained multipliers. However, despite the cost of production being relatively low, estimated at 894,355.6 CFA/ha for a yield of 4.4 tons/ha, multipliers do not have the operational means to expand or improve autonomously. For instance, there is a lack of access to a consistent

[55] The strategic geographical area of intervention for AfRC

credit system, agricultural equipment, and qualified human resources to be able to fulfil their mission of producing seeds on a larger scale (EU, 2015).

INPA's limited resources reduces its mandate down to a seed producer. Varietal research as it currently stands involves the introduction and evaluation by INPA of varieties developed by different regional and international organisations to identify those that adapt well to local conditions. But also the selection and dissemination of the most successful local varieties with the participation of farmers in the process (e.g. Participatory Varietal Selection (PVS))[56]. The lack of resources needed to carry out a breeding program limits the range of varieties that meet farmers' requirements. Agricultural research in the particular case of agricultural rice is limited by the lack of human and financial resources required for the operation of INPA's rice research program. To this must be added the lack of a specific strategic plan for agricultural research in Guinea-Bissau. The development of this strategic plan is currently a major priority for this agricultural research institution. Despite the reconstitution of the seed sector being already part of the government's strategic and operational plan, Terra Ranka (2015-2025), the current state of political instability is likely to undermine these ambitions.

This section had the objective to provide insights on the Social, Economic and Political Settings (S), a key component of the Socio-ecological Systems (SES) framework that is determinant in understanding the broader context into which the socio-ecological system being analysed. Namely by providing information on Economic development (S1), Demographic trends (S2), Political stability (S3) as well as some historical background on the evolution of rice production and the formal seed systems, in Guinea Bissau. This background provides valuable information on the likelihood of the **interactions** under analysis, such as interactions between alternative governance systems, might affecting farmers' rights the outcome being studied. (See section 2.3 for details on the SES framework and section 6 for interaction analysis and outcomes)

[56] See Appendix 4 for a detail on the PVS process

4. Resource System and Units

This section will focus on two core sub-systems of the framework: the Resource System (RS) and Units (RU) variables (n.b. highlighted in the scheme in dark orange). With respect to the **resource units,** it will cover the following variables, disaggregating by seed as “artifact” and seed as “ideas” according to the SES framework discussed above, while for the resource system it will look at different system variables.

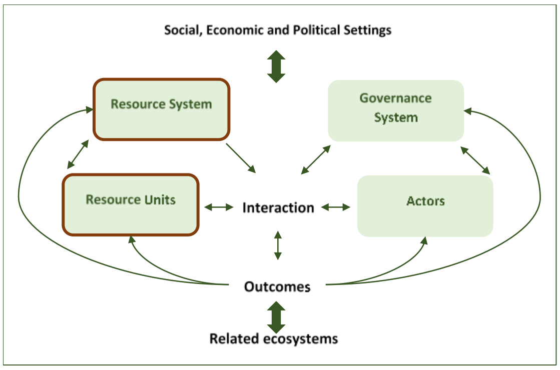

Figure 3. Social-ecological system: Resource System (RS) and resource Units (RU

The following table presents the variables that are going to be described (See Appendix 2 First and Second-tier variables of a social-ecological system for details on the second tier variables). These variables are underlined along the text.

Table 3. Second Tier Variables for Core Sub-systems: Resource Unit and Resource System

Resource Unit variables	**Resource System Variables**[57]
RU1 – Resource unit mobility	RS1 – Sector
RU2 – Growth or replacement rate	RS2 – Clarity of system boundaries,
RU3 – Interaction among resource units	RS3 – Size of resource system,
RU4 – Economic value	RS4 – Human-constructed facilities
RU5 – Number of units,	RS5 – Productivity of system
RU6 – Distinctive characteristics	RS9 – Location
RU7 – Spatial and temporal distribution.	

In common pool resources research, the distinction between resource system and resource units has been tailored to analyse the impact of different property rights on the incentives of participants

[57] No data available to RS6 – Equilibrium properties, RS7 – Predictability of system dynamics, RS8 – Storage characteristics

regarding resource systems and resource units related to water, fisheries, and other natural resources. However, the complex configuration of seeds as a good, makes this framework inadequate to think about issues regarding farmers' rights over seeds. In the context of research of information and the intellectual public domain, Hess and Ostrom (2003) propose instead as a three-way distinction between the artifact, the facility, and ideas. This approach to characterise the Biophysical Characteristics (as per IAD framework) or the Resource System and Resource Units sub-systems (as per Socio-ecological systems frameworks), is also a useful framework to characterise this particular resource – seeds.

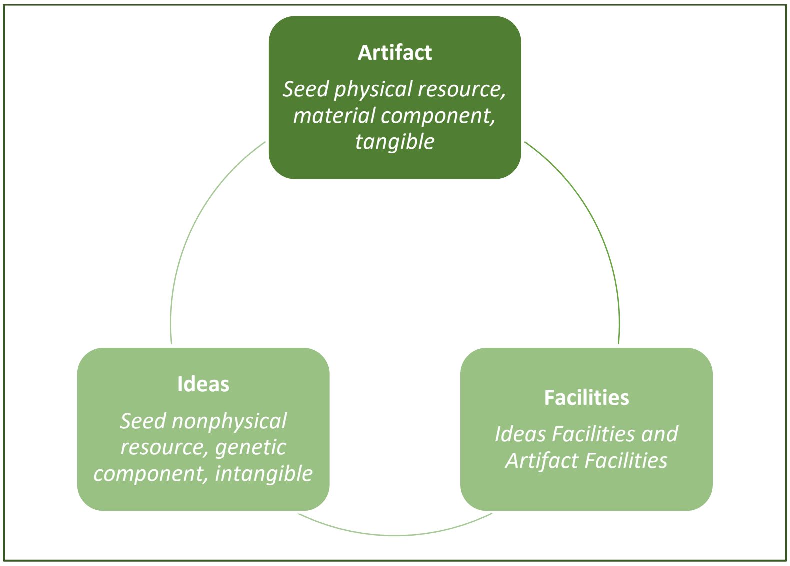

Figure 4. Ideas, Artifacts and Facilities: Seed as a common-pool resource

Figure 4 shows how this particular sub-framework fits into the broader framework to analyse socio-ecological systems. The conceptualization of Resource Systems and Units, as Ideas, Artifacts and Facilities, is useful and appropriate to understand these sub-systems. However, it must be merged to with the Resource Systems and Units second-level variables under first-level core subsystems (e.g. Resource System, Governance System etc) (See Appendix II First and Second-tier variables of a social-ecological system) in order to provide a clearer picture of the complexity of these subsystems. In discussing the essential elements of intellectual property and its common ownership structure, it is not possible to separate the ideas, the artefact and the facilities from some of the broader elements of the resource and governance systems. As already mentioned this sub-framework emanates from the new commons literature particularly in the context of knowledge (e.g. Hess & Ostrom, 2003)

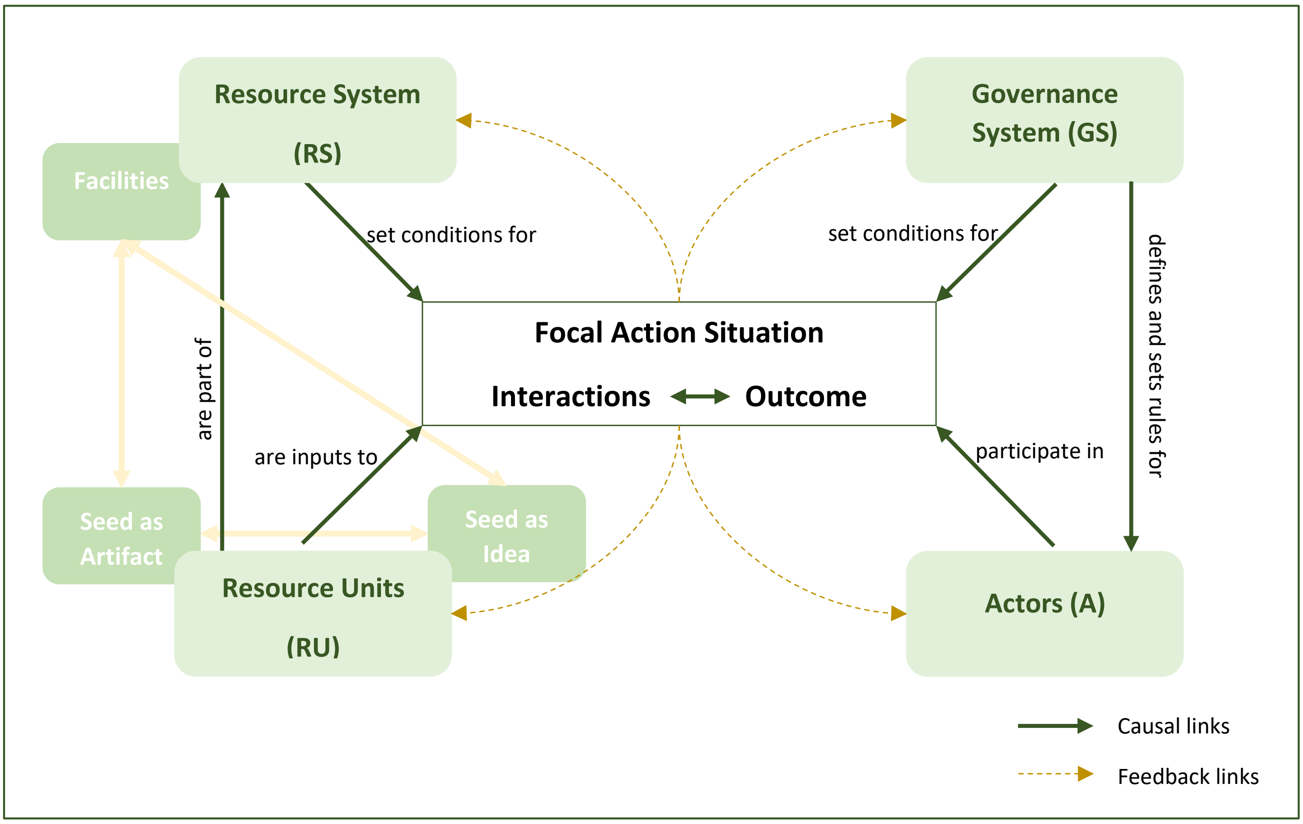

Figure 5. Action Situation (Source: Adapted from McGinnis & Ostrom, 2014; Hess & Ostrom, 2003)

Having described in general terms this sub-framework and how it fits in the overall framework for socio-ecological framework analysis, I move to describe and characterise, seed systems, seed units and flows of information within seed as follows. I use the framework suitably adjusted for the case in hand, in order to characterise the governance of seeds in Guinea Bissau and examine interactions between different governances systems potentially affecting *rules in use* that provide lowland rice farmers with seed sovereignty-related rights. The following sub-sections will characterise seeds, the resource unit in its two forms, as idea and artefact as well as the resource system- the lowland agro-ecological system.

Resource Unit (RU) - Seed as Artifact

An **artifact** is a discreet, observable, nameable representation of a seed. In the context of seeds, an artifact represents the physical, tangible component of a seed. Artifact is the seed as a product and source for the cultivation of plants. Artifacts are the physical flow units that can be moved from one seed facility to another. Users can usually be excluded from using physical artifacts of seeds. Seed's mobility as a physical unit, occurs throughout the agricultural food production system in the quality of an agricultural input. Growth of quantity of seed dependents particularly on agricultural production which is a function of production factors, such as inputs (e.g. land, fertilizer, labour, pesticides, machinery), individual characteristics (e.g. ability), farms characteristics (e.g. soil, slope, fragmentation) and climate (e.g. rain etc) (Di Falco, Bezabih, & Yesuf, 2010). The economic value of seeds as agricultural input can be quantified in its market value in well-developed mature seed systems. In seed systems, relying mainly on the informal sector is more difficult to measure as seeds are mainly obtained from own saved seed and from farmers social networks. Nonetheless, Bonny (as cited in McGuire & Sperling, 2016, p.180) presents recent figures on the seed market valuation estimating the commercial value of both seed sectors, with the formal sector being valued at $US 45 billion annually and the informal sector at between $US 6 and 15 billion annually. However, as pointed by McGuire and Sperling (2016) if the same analysis was undertaken in the south, these figures would most likely show greater balance between the market sizes of these two sectors, with a greater expresion of informal sector. The number of units is the quantity of seed available in a certain area from different sources from both formal and informal sectors, such as farmers saved seed, seed agro-multipliers/producers, local markets and agro-dealers. The spatial distribution of physical seed is intimately related to the agricultural production systems, placed particularly in rural areas, where there are farms, agricultural production connected to seed formal and informal systems. Regarding temporal distribution, this is highly dependent on production conditions of each moment in time, climate conditions, labour availability and other time-invariant factors are critical to seed availability.

Resource Unit (RU) - Seeds as Ideas

The **ideas** contained in an artifact can be understood as the intangible content of seeds and traditional knowledge associated with that content. Ideas are the nonphysical flow units contained in an artifact. In the context of seeds, **the ideas** are the genetic material contained in a seed's physical subset, the artifact - and the traditional knowledge associated with that genetic material. In theory, one person's use of the genetic information does not subtract from the corpus of that idea for use by others. It may, however, be possible to exclude others from the seed "idea" by imposing Plant Variety Protection regimes, for example. Regarding mobility, the genetic resources contained in seeds can flow across different facilities, can be more or less fluidly according to the geographical, social distance and the rules involving these exchanges. There is extensive evidence that germplasm mobility through exchanges between farmers responsible for different *in situ facilities* can be said to be relatively fluid

(Coomes, McGuire, Garine, Caillon, McKey, Demeulenaere, & Emperaire, 2015) however they are ruled by trust and social norms of reciprocity (Coomes et al., 2015; McGuire, 2008). While mobility from *in situ* conservation (on farm) to *ex situ* conservation (e.g. community seed banks and international genebanks) and conversely from *ex situ* to *in situ* facilities, is less fluid given the geographical distance between *ex situ* and *in situ* as well given the complex rules and procedures involving these transactions. Nonetheless, by design, the flow of germplasm is much higher from *in situ* to *ex situ* facilities than in the other direction. Nonetheless, seed networks within the informal seed system are undoubtedly the most frequent and long-standing means by which seed genetic resources are transferred geographically/mobile, particularly in developing countries (McGuire, 2008; Mayet, 2015; Coomes et al., 2015). Growth of seed genetic resources is largely dependent on the individual aggregation of agro-biodiversity efforts or erosion (Timmermann & Robaey, 2016). Agro-biodiversity, is mainly maintained and developed by farmers in the informal seed system (Visser, Eaton, Louwaars, van der Meer, Beekwilder, & van Tongeren, 2001; Upreti & Upreti, 2001; Carpenter, 2004; Mokuwa et al, 2014). While there is extensive evidence that genetic erosion[58] occurs in areas of crop domestication, where the abandonment traditional cultivars was hand in hand with specialization and intensification of agricultural development (Harlan, 1992; Smith & Williams, 1987; Pistorius and Van Wijjk, 1999). Hence, genetic erosion can be seens as essentially an aggregative harm, while agrobiodiversity is an essentially aggregative good (Kahn, 2014). Ultimately, as presented in Box 1, evidence shows that agrobiodiversity is in decline due to genetic erosion.

Box 1 100 Years of Agricultural Change: Some Trends And Figures Related To Agrobiodiversity

** Since the 1900s, some 75 percent of plant genetic diversity has been lost as farmers worldwide have left their multiple local varieties and landraces for genetically uniform, high-yielding varieties.*

** 30 percent of livestock breeds are at risk of extinction; six breeds are lost each month.*

** Today, 75 percent of the world's food is generated from only 12 plants and five animal species.*

** Of the 4 percent of the 250 000 to 300 000 known edible plant species, only 150 to 200 are used by humans. Only three – rice, maize and wheat – contribute nearly 60 percent of Calories and proteins obtained by humans from plants.*

** Animals provide some 30 percent of human requirements for food and agriculture and 12 percent of the world's population live almost entirely on products from ruminants.*

Guendel, Sabine. "What is agrobiodiversity?" In FAO. Building on Gender, Agrobiodiversity and Local Knowledge. Rome: FAO, 2005. p. 3. Available at: www.fao.org/3/a-y5956e.pdf.

[58] Maxted & Guarino (2006) define genetic erosion as follows: "Genetic erosion is the permanent reduction in richness (or evenness) of common local alleles, or the loss of combinations of alleles over time in a defined area."

The interaction between units can be seen as breeding efforts to combine different varieties into new varieties with desired attributes to farmers. Breeding can take place in both the formal and informal seed sector. It is worth pointing that rice related biodiversity development, and consequently interaction between units, is mainly maintained by farmers in the informal seed system as already mentioned above. However, interactions between units also occur between the informal and the formal sectors. Germplasm developed by private breeders is tested by farmers under their specific conditions and recombined with their own germplasm to improve that germplasm and 'breed' new varieties and breeds (Hardon, Duvick & Visser, B., 2000). The same interaction applies to the public sector, represented by the national agricultural research systems and international agricultural research institutes (NARS and CGIAR) (Visser et al., 2001). Finally, the number of units can be represented as the number of varieties of rice worldwide. The number of rice cultivars being grown in the world exceeds 40,000 (Chauhan, Jabran, & Mahajan, 2017). Regarding spatial distribution, agrobiodiversity *in situ* is highly concentrated in the global south, in developing countries (Di Falco, 2012; Andersen, 2013). Particularly concerning rice, the map below illustrates the origins of most rice accessions in international genebanks showing the spatial distribution of rice agro-diversity maintained *ex situ*.

Map 1. Origins of georeferenced rice samples by Genebank (Source: IRRI 2011)

Despite the lack of data on *in situ* rice agro-diversity, this map can be interpreted as a proxy for world-wide diversity, showing that rice agrobiodiversity is localised mainly in West Africa and in Asia. Looking specifically at agro-biodiversity, at the scale of the socio-ecological systems being studied, it seems that farmers' relative isolation from the formal seed system may have granted relatively untouched rich rice related agro-biodiversity. Guinea Bissau's seed system has historically been predominantly informal (see Section 3b on the History of Rice Sector and Seed Systems). As stated above there is evidence showing that although genetic erosion occurs in areas of crop domestication with the abandonment traditional cultivars, this was not the case of Guinea Bissau. In the case of mangrove agro-ecology in Guinea Bissau, Temudo (2011) notes that poor adoption rates by farmers of modern rice varieties are the result of poorly focused research and development priorities and total disconnection between breeders' selection criteria and farmers' needs. It is likely that similar issues existed in the lowland rice agro-ecosystem. **Appendix III** Local Seed Varieties and Improved, provides some support to this hypothesis since only 3 out of 734 sample plots reported using improved Nerica rice varieties. Also from the 31 varieties introduced in the lowland agrosystem in the past ten years, there is no reference to Nericas or any other improved variety in any of the reported varieties used by farmers. The same Annex also shows that are 74 names of varieties identified in the sample of 310 farmers of Contuboel Sector (See Section 2.1 or Chapter 2 for more detail on Study area). Nonetheless it is important to note that different names of varieties do not necessarily mean different varieties since many varieties are named at the women that has introduced them to the villages. In order to identify different varieties genetic tests would need to be carried therefore this assertions need to be taken with caution. Although accurate information on lowland rice agro-biodiversity is inexistent, these findings suggest that rice agro-biodiversity might be relatively preserved. It is worth pointing that rice seeds are open pollinated means that seed can be saved from one generation to the next without losing characteristics and performance of that variety. This is particularly relevant in the context of PVP and Quality Control and Certification (See sections 5.2 and 5.3) related laws since the farmers' lowland rice varieties are not as distinct, uniform and stable as the varieties arising from the formal breeding sector. Since they do not satisfy these registration requirements they cannot be legally sold (Munyi & De Jonge, 2015).

Now that the Resource Units have been characterized as Seed as artifacts and ideas in the context of the SES, the next section discusses the Resource System through which these artifacts and ideas flow.

Resource System (RS)

The **resource system** can be characterised by many variables including its facilities. A **facility** stores artifacts and makes them available. While it is the resource system that stores artifacts and their embedded information. A facility has a physical limit on the number and type of artifacts that could be stored. The costs of excluding users is very much dependent who would be considered legitimate users, for how long individuals could legally remove artifacts/ideas from the facilities, and the practices that are to be followed within the facility and in the use of the artifacts and ideas. It also depends on the monitoring and enforcement activities associated with the facilities, e.g. guards. Facilities in the context of seed can be grouped as *ideas focused facilities,* e.g. when the function of the facility is to store genetic diversity, or *artifact focused facilities* if the function relates to the provision of the artefact itself. Ideas focused facilities can be in turn grouped in *In situ* and *Ex situ* where *In situ* facilities can be seen as the land where seeds genetic diversity in conserved in wild areas or areas of cultivation. *Ex situ* facilities relate to off-farm infrastructures were seeds genetic resources are kept: community seed banks and genebanks (e.g. at the Africa Rice Centre). Artifact facilities are infrastructures that contain seed for its purely physical tangible purposes, seed as an agricultural input. Such infrastructures can be in informal markets stores, household storage, community-based organisations, agro-dealers or formal retail stores.

However, the resource system is more than just facilities storing seed artifacts and ideas. In the particular context of this case study, <u>the main resource system (RS) to be considered and characterised is the lowland agro-ecological system</u> in the east region of Guinea Bissau. The lowland agro-ecological system has clear boundaries with the exception of the storage type facilities described above. The lowland agro-ecological system has well-defined <u>boundarie</u>s and is <u>located</u> in Geba Valley. The system of rice production in *basfonds* is present in all agro-ecological zones, but with greater relevance in the Eastern part of the country, where a potential <u>size</u> of 25,000 hectares of irrigable *basfond* exist in the Geba River valley alone. It is estimated that a total potential of 200,000 hectares are available for this type of rice production in the country. Although a small fraction (13.5%) of these potentials is utilized. The <u>production efficiency</u> in these valleys is between 600 - 1200 kg/ha. The total annual production of *basfonds* (rainfed and irrigation water) is historically about 10% of national production (RGB, 2014).

5. Governance System

This section will characterize the governance system (GS) unit that is one of the core sub-systems of the socio-ecological systems of seeds (highlighted in the figure below).

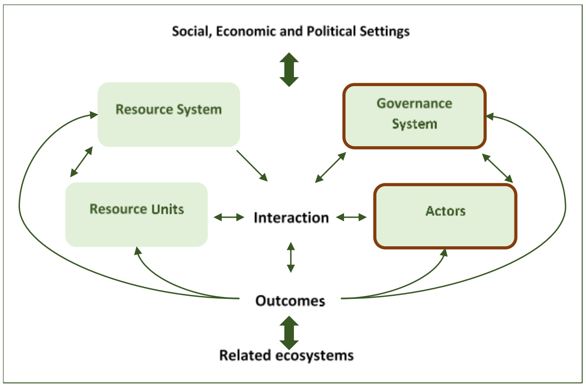

Figure 6. Social-ecological system: Governance System (GS) and Actors (A)

With respect to the variables that describe each unit of the Socio-ecological system, for the Governance System they will be drawn from the alternative list of second-tier properties for governance systems as proposed by McGinnis and Ostrom (2014) notably: GS1 – Policy areas, GS2 – Geographic scale of governance system, GS3– Population, GS5 – Rule-making organisations, GS6 – Rules-in-use, GS7 – Property-rights systems. The variables GS4 – Regime type, GS9 – Network structure, and GS10 – Historical continuity - also describe the governance system, will be covered in section 6 since they are informative and supportive in analysing the multi-level interactions and its effects on the outcome of farmers' rights. Since there is an overlap between Rule-making organisations (GS5) and Actors (A) SES core sub-system, this section will also cover Actors summary description (For a detailed description on the Rule Making Governance Organisations (and Actors) at the Meta-Constitutional, Constitutional and Collective level, please refer to **Appendix I**).

A governance system is characterised, among other things, by the relation between multi-level rulemaking organisations and how the rules flow among them, as illustrated in **Figure 7**. Meta-constitutional level organisations establishing the meta-rules of the game, define the rules that can affect all other levels across the board. The constitutional level of analysis here refers to the rules defined at a supra-national regional level (West Africa) that affect the rules at the collective-choice level. The second level is the collective-choice (or policy) level of analysis where individuals interact to make the rules that affect the operational level. In the case of seeds the collective choice/policy level refers to Policies and laws devised the Bissau Guinean government national level covering and affecting the operational rules concerning who may save, use, exchange and sell seed.

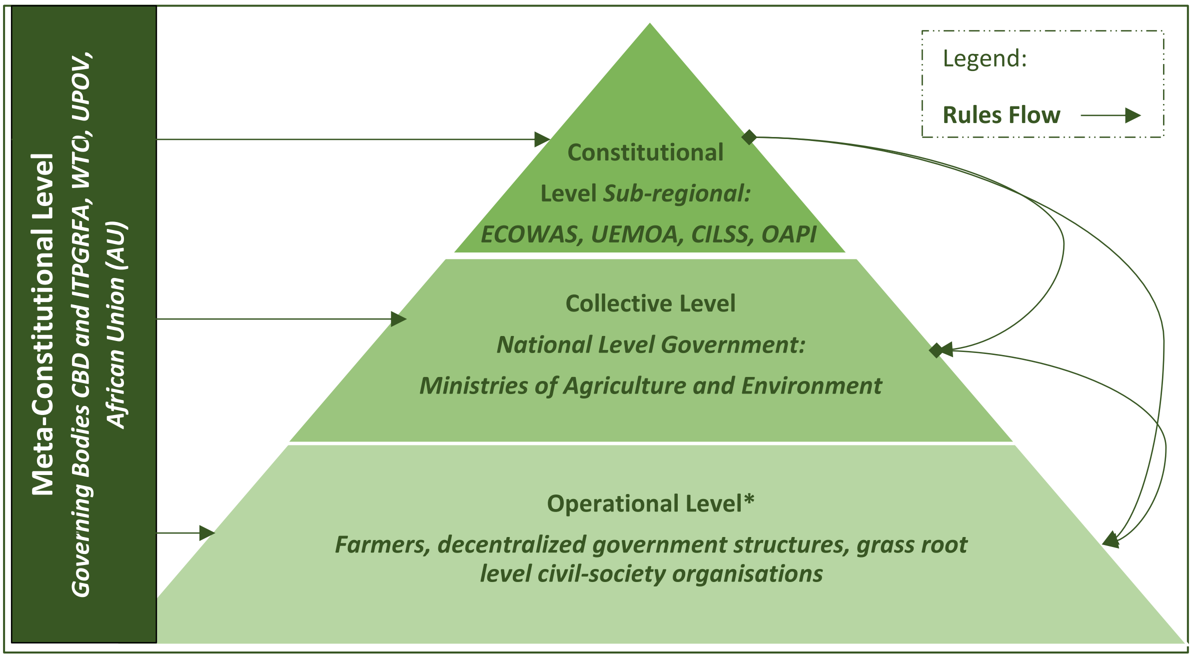

Figure 7. Levels of Social Interaction in a Socio-ecological Seeds System
Source: Adapted from Ostrom (2005, p. 59); *includes an intermediate collective-choice level

Finally, at the operational (and intermediate collective) level, we have farmers, decentralised government structures, grass root level non-organisations interacting with each other and the relevant physical/material world. These are rules that emanate from and patterns of interaction among individuals in their ordinary dealings in society in accordance (or not) with various meta-constitutional, constitutional and collective rules. Operational rules will define who may save, use, exchange and sell seed at the operational level. Choices made at each level have outcomes, as well as outputs that can affect the Resource System and Units, the Governance Organisations, and *rules in use* at other levels.

Since the majority of rules being produced at the meta-constitutional, constitutional and collective levels are predominantly rules-in-form, while the ones at the operational level and to a lesser extent also at the collective level, are rules-in-use, this section will be structured according to two different governance systems that are simultaneously operating. Hence I have classified **Governance *in Form*,** the governance system that produces rules in the form of laws or legislation, that are typically not either known by participants or not enforced, and **Governance *in use*,** the governance system that emanates normative instructions that are known and enforced and affect those interacting. I argue that although not *in use*, rules that emanate from the formal governance system, might be making their way to become *rules in use* and can pose serious risks to farmers' rights and therefore are worth being included.

5.1. Seed Governance *in Form*

The policy area of the governance system concerns biodiversity and farmers rights (GS1). The analysis of the governance system, in this case, must take place at two different scales. Two kinds of scale need to be considered when analysis a governance system: the geographic range (GS2) as well as the size of the population (GS3) that participates in, or is subject to, that system of governance.

The geographic scale (GS2) for the seed **governance *in form*** system is global because there are global rules that apply to the use of seeds and the intellectual and traditional property that they embody. Particularly regarding rural areas around the world which produce food through millions of agro-ecological systems. While the population subject (GS3) to the system of governance considered is all farmers in the world to which the livelihoods are dependent on the resource system that is subject to this governance system. The following subsections will present in detail the following variables: GS5 – Rule-making organisations, GS6a *Rules in form* and GS7 – Property-rights systems. In this section, I will list all organisations, all the *rules in form* and the property rights systems associated with the different rules that are applicable at the local level and which can affect farmers' rights.

a. Actors and Rule Making Organisations

Table 4 below presents a summary of the key actors and governance organisations at each level of rulemaking. To place these different organisations in context with respect to other sections, **Table 4** relates each organisation with the type of rules (*in form* or *in use*) (see the following sub-sections b and d). It also identifies whether these rules affect issues related to Intellectual Property Rights (Seed as an Idea) or are Non-Property Rights Related (Seed as an Artifact) (See the previous section 4.1 on Resource Systems and Units).

Table 4. Multiple Levels Rule Making Organisations and Rules

	Governance Organisations	**Non PVP Related Rules >Seed as an artifact**	**PVP related rules >Seed as an idea**
Meta-constitutional Level	▪ Governing Bodies Convention on Biological Diversity (CBD) and ITPGRFA > Non PVP Related Rules	▪ *Rules in form*>Convention on Biological Diversity, Nagoya Protocol, ITPGRA	▪ *Rules in form*>TRIPS; UPOV ▪ *Rules in form*>African Union Model Law

	▪ WTO, UPOV, WIPO> PVP Related Rules ▪ African Union (AU) > PVP and Non-PVP Related Rules		
Constitutional Level	▪ ECOWAS/CILSS/UEMOA – Both PVP and Non PVP related organisation ▪ EU-ECOWAS– Both PVP and Non PVP related rules ▪ OAPI> PVP Related rules	▪ *Rules in form*>Harmonization Seed Regulations ECOWAS/CILSS/UEMOA	▪ *Rules in form*>EU West Africa (ECOWAS) Economic Partnership Agreement ▪ *Rules in form*>OAPI: Agreement Revising the Bangui Agreement of March 2 1977 (1999)
Collective Level	▪ The government of Guinea Bissau ▪ Ministry of Agriculture ▪ INPA	▪ *Rules in form*> Seed Policies and regulations	▪ *Rules in form*> Intellectual property rights legislation
Intermediate Collective Level/ Operational Level	▪ Local government: INPA and Regional Directorate of Agriculture at regional level ▪ Lowland Farmers ▪ Civil Society Organisations ▪ NGOs	▪ *Rules in use*> Customary rules; Rules introduced by development projects/organisations	▪ *Rules in use*>Customary rules; Rules introduced by development projects/organisations

Please note that these institutions represent at the same time rulemaking organisations and are as well actors interacting in a multi-level action situation. Given the greater importance to the current analysis of the Actors operating at the Intermediate Collective Level and Operational Level, the second tier variables[59] are only described for this group (See section 5.2.). Notwithstanding, a brief presentation is provided for Actors and Rule Making Governance Organisations at the Meta-Constitutional, Constitutional and Collective level, please refer in **Appendix I**.

[59] **Appendix II**

b. Rules in Form

This section presents a brief overview of the legal framework defined by international, regional and national governments underlying three interconnected governance systems: (i) Biodiversity and Farmer's rights, (ii) Plant Variety Protection and (iii) Quality Control and Certification. The shift from the locally managed to formalised and globally networked pool contributed to Plant genetic resources for food and agriculture (PGRFA) becoming a subject of global interest, international legal regulation and concern (Halewood et al., 2012).

Convention of Biological Diversity (CBD) and International Treaty Plant genetic resources for food and agriculture (ITPGRFA)

Two key mechanisms are aiming at protecting biodiversity and farmers-rights. The Convention on Biological Diversity entered into force on 29 December 1993 with three primary objectives: conservation of biodiversity, sustainable use of its components and equitable sharing of benefits from the use of genetic resources. The International Treaty on Plant Genetic Resources to Food and Agriculture (ITPGRFA) adopted later in 2001 was a response to the increasing power of breeding rights in the international legal arena, notably Trade-Related Aspects of Intellectual Property Rights (TRIPS) for World Trade Organisation (WTO) and Union for the Protection of New Varieties of Plants (UPOV). The Treaty in its preamble recognizes farmers rights as "the past, present and future contributions of farmers in all regions of the world in conserving, improving and making available these resources, constitute the basis of farmers' rights, as well as the right to save, use, exchange, and sell farm-saved seed and other propagating material, to participate in relevant decision-making, and in the fair and equitable sharing of benefits arising from the use of PGRFA" (Andersen, 2006, p.105; De Boef et al., 2013). While the CBD does not explicitly recognize farmers' rights, Article 8 (j) states that knowledge, innovations and practices of local communities and indigenous populations should be respected, and application of this knowledge should be encouraged by means of approval and participation of its holders and benefit sharing with local and indigenous communities (Andersen, 2006; Santilli, 2012).

The principles of access and benefit sharing[60], are enshrined in both the Convention on Biological Diversity, through the Nagoya Protocol, and the ITPGRFA. The ITPGRFA came into force in 2004 establishing the 'multilateral system of access and benefit sharing' for 64 specifically identified crops and forages, namely rice. The multilateral system had as main objective to support the virtual pooling

[60] Access and benefit-sharing (ABS) refers to the way in which genetic resources may be accessed, and how the benefits that result from their use are shared between the people or countries using the resources (users) and the people or countries that provide them (providers) in https://www.cbd.int/abs/infokit/brochure-en.pdf

and management of plant genetic resources, as inputs into plant breeding, agricultural research and conservation efforts. The Nagoya Protocol is an international treaty that builds on and supports the implementation of the Convention Biological Diversity, and focus particularly on one of the three objectives stated above: the fair and equitable sharing of benefits arising from the utilisation of genetic resources[61]. There are key differences between ITPGRFA, CBD and Nagoya protocol. The multilateral system established under the ITPGRFA is different from the Access and Benefit Sharing system that arises from the CBD. In the ITPGRFA, the benefits arising from the utilisation of PGRFA are not shared with the provider but go instead to a common fund to support indigenous and local communities. Conversely the Access and Benefit Sharing (ABS) system included in the CBD, benefits are expected to be directly shared with the provider through bilateral agreements. Regarding the scope, the Nagoya Protocol goes beyond plant genetic resources for food and agriculture, including genetic resources used for industrial purposes, and also applies to the traditional knowledge associated with genetic resources.

Until now, only a relatively small number of national governments have tried to design and enact meaningful and effective measures to implement farmers' right and plant genetic resources related legislation (Pistorius, 2016). There is a clear obligation for countries party to the ITPGRFA to take steps for protecting and promoting farmers' rights and to develop policies that promote the sustainable use of plant genetic resources, even if this means revising existing policies (Christinck & Tvedt, 2015). The ITPGRA gives guidance on measures to be implemented at the national level such as farmers' Rights[62] (Hallewod, 2016), a Multilateral System facilitating access to crop genetic resources and on a benefit-sharing mechanisms, to support initiatives for the conservation and sustainable use of crop diversity in developing countries (Andersen, 2006; Santilli, 2012).

The CBD, on the other hand, prescribes as main areas to promote farmers rights and PGRFA management, notably: (i) material transfer agreements; (ii) transfer of biotechnologies to developing countries; and, (iii) public investment *in situ* and *ex situ* conservation (Andersen, 2006). Both instruments have been subject to criticism regarding the implementation difficulty at the national level (e.g. Santilli, 2012; Christinck & Tvedt, 2015; Pistorius, 2016; Rosendal, 2010; Brink, 2013; Halewood et al., 2016).

[61] https://www.cbd.int/abs/infokit/revised/web/factsheet-nagoya-en.pdf
[62] a) protection of traditional knowledge relevant to plant genetic resources for food and agriculture; b) the right to equitably participate in sharing benefits arising from the utilization of plant genetic resources for food and agriculture; and c) the right to participate in making decisions, at the national level, on matters related to the conservation and sustainable use of plant genetic resources for food and agriculture.

TRIPS, UPOV and OAPI Agreements

There are three main legal interrelated instruments ruling seeds in the context of Plant Variety Protection (PVP): i) the Union for the Protection of New Varieties of Plants (UPOV) (1991); ii) Trade Related Intellectual Property Rights (TRIPs) (1994); and, iii) the EU-West Africa Economic Partnership Agreement (2014).

The WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) is an international agreement by all WTO nation members. The agreement sets down minimum standards for the regulation by national governments of many forms of intellectual property as applied to nationals of other WTO member nations (TRIPS, 1995). Until the WTO's Uruguay Round, intellectual property laws were a matter of domestic policy, however, the TRIPS Agreement made it mandatory for all WTO members to provide for internationally acceptable and enforceable patent protection for new inventions in all areas of technology. In the particular context of seeds, TRIPS enforces developing countries to extend intellectual property rights to plant varieties and seeds with consequential impacts on agriculture and farmers (TRIPS, 1995). Although it is argued that TRIPS provides sufficient flexibility[63] to modulate patent protection as a function of their needs, interests or ethical standards, it is not clear whether, in a context of a dispute under the WTO, developing countries will be able to enforce the claimed leeway in the agreement (Halewood, 2016; De Jonge & Munyi, 2016).

The UPOV system was initially conceived in 1961 as a particular form of protection covering only plant varieties having the underlying assumption that plants should not be subject to patents. In the same way as the "effective *sui generis* system" under Article 27b of TRIPS, in 1961 UPOV was a *sui generis* form of protection, and an alternative to the patent system (FAO,2000). One of the main objectives of Plant Variety Protection (PVP) is to encourage plant breeding by granting breeders of new plant varieties the exclusive rights to commercialize registered varieties (Louwaars, Tripp, Eaton, Henson-Apollonio, Mendoza, Muhhuku & Wekundah, 2005; Tripp et al., 2007; De Jonge & Munyi, 2016). While stimulating investments in research, developing the domestic seed sector, and allow countries to take advantage of foreign technology (International Seed Federation, 2003 as cited in Tripp et al., 2007).

However, notwithstanding the potential benefits to breeders and seed producers there is an extensive concern in both academia and civil society, about the possible benefits and the dangers resulting from

[63] Article 27.3(b) effective *sui generis* system, in conjunction with Article27.2 (exclusion from patentability of inventions the commercial exploitation of which is necessary to protect public order or morality) and Article 27.1(patentability criteria) provide developing countries with considerable leeway

the concentration of technology ownership with detrimental effects to farmer seed systems. In its current version, UPOV makes it illegal for farmers to save, exchange or modify seeds from so-called protected varieties. Under the 1991 UPOV, protection shall be provided for all plant varieties for 20 to 25 years (Helfer, 2004) and inhibits farmers and breeders from exchanging protected seeds during this period (Christinck & Tvedt, 2015; De Jonge, 2016). Moreover, national Plant Variety Protection (PVP) laws of a country are reviewed and approved before granting membership, reducing the possibilities of states to have PVP laws that are context specific to each countries' needs (Christinck & Tvedt, 2015). Some argue that this law, which will provide patent-like rights for plant breeders, main objective is to boost profits for multinational seed companies (Christinck & Tvedt, 2015). The 'farmers' privilege' referred in previous versions of the UPOV Convention, that could be regarded as a recognition of certain elements of farmers' rights, is now an optional exception. Even if adopted to domestic PVP law, it states that farmer's privilege needs to be regulated "within reasonable limits and subject to the safeguarding of the legitimate interests of the breeder..." (UPOV, 2009, p. 14). Overall UPOV requirements if transposed to PVP domestic law will become a legal tool that will undermine economic development of smallholders, an already marginalised group (De Jonge, 2014; Christinck & Tvedt, 2015; De Jonge, 2016).

Guinea Bissau is also a member of OAPI, the leading organisation on the protection of intellectual property rights in most West African countries. Guinea Bissau became a signatory of the Bangui Accord on 8th May 1998, and with effect from 8th July 1998 all patent, trademark and design applications filed at OAPI cover Guinea Bissau in addition to the existing 14 member states. The revised Bangui Agreement (2002) included an Annex X, certified by UPOV council, as complying with UPOV 1991, that establishes a regional PVP regime applicable to the 17 members of OAPI (Strba, 2017). This revised Bangui Agreement came into force in 2002 for all OAPI members, including the 13 LDC members, namely Guinea Bissau who are not yet obliged to provide PVP under Article 27.3(b) of the TRIPS Agreement. More recently OAPI joined UPOV 1991 in June 2014, becoming the first African regional institution to do so (Haugen, 2015; Strba, 2017). When their member states' lack of national Intellectual Property laws, OAPI provisions them with automatic and unified protection. Which is the case of the majority of West African countries since few OAPI members have yet implemented PVP at the national level (Haugen, 2015; Strba, 2017).

EU-West Africa Economic Partnership Agreement

The EU-West Africa Economic Partnership Agreement is a bilateral trade treaty between West African Countries[64] covering goods and development cooperation to help West Africa to integrate better into the global trading system and will support investment and economic growth in the region[65]. However bilateral free trade agreements, such as EU-West Africa negotiated outside the WTO, especially those initiated by powerful economies in the global North, tend to go much further (Halewood et al., 2012). These agreemetns often require countries to patent plants or animals, follow the rules of the Union for the Protection of New Plant Varieties (UPOV) to provide a patent-like system for seeds and to join the Budapest Treaty (GRAIN, 2014). These requirements are particularly relevant since Guinea Bissau is part of this agreement which under Article 11 establishes that “Parties shall provide for the protection of plant varieties”. This means that parties shall ratify or accede to the “International Convention for the Protection of New Varieties of Plants – UPOV (Act of 1991)” and “shall have the right to provide for exceptions to exclusive rights to allow farmers to save, use and/or exchange protected farm-saved seed or propagating material, subject to national law as appropriate and in line with the applicable international rules” [66]. The first is directly imposing ratification of UPOV to member parties while the later is reinforcing the transposition of farmer's privilege provision under the same UPOV.

ABS principles under the ITPGRFA and CBD are also reflected in the EU-West Africa Economic Partnership Agreement. With respect to ABS related principles Article 12[67] states that “Subject to their national legislation the Parties respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the involvement and approval of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices”. Under this article parties shall also take “appropriate measures, subject to national legislation, to preserve traditional knowledge and agree to further work towards the development of an internationally agreed *sui generis* model for the legal protection of traditional knowledge”. However when it comes to genetic resources related ABS, the parties “agree that the patent provisions

[64] Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo
[65] http://ec.europa.eu/trade/policy/countries-and-regions/regions/west-africa/
[66] Idem
[67] Genetic resources, traditional knowledge and folklore

of this Title and the Convention on Biological Diversity shall be implemented in a mutually supportive way" and "to regularly exchange views and information on relevant multilateral discussions" such as in the context of the World Trade Organisation (WTO) and World International Patent Organisation. Which can result in the "review of this Article in the light of the results and conclusion of such multilateral discussions". Despite recognising farmers' rights under the CBD, the economic partnership agreement points to the need to balance these rights with other more stringent international legislation, particularly concerning intellectual property rights over genetic resources. Two other regions – Southern African Development Community (SADC) and East African Community (EAC) – have also concluded regional Economic Partnership Agreements (EPAs), but the likelihood of signature is in doubt in West Africa and the EAC.

African Law Model[68]

The first important effort to regulate plant varieties and address food security in Africa was the 'The African Model Legislation on the Protection of the Rights of Local Communities, Farmers and Breeders, and for the Regulation of Access to Biological Resources´, proposed by the then Organisation of African Unity (Strba, 2017; Andersen, 2006; Applequist & Brown, 2008). The Model Law granted farmers exclusive rights including the rights to use, save, sell and exchange seed or propagating material. In particular, farmers' rights would include the right to (a) the protection of their traditional knowledge relevant to plant and animal genetic resources; (b) obtain an equitable share of benefits arising from the use of plant and animal genetic resources; (c) participate in making decisions, including at the national level, on matters related to the conservation and sustainable use of plant and animal genetic resources; (d) save, use, exchange and sell farm-saved seed/propagating material of farmers' varieties; (e) use a new breeders' variety protected under this law to develop farmers' varieties, including material obtained from gene banks or plant genetic resource centres; and (f) collectively save, use, multiply moreover, process farm-saved seed of protected varieties. Under the law, farmers' varieties and breeds are recognised and must be protected under the rules of practice as found in, and recognised by, the customary practices and laws of the concerned local farming communities, "whether such laws are written or not" (Santilli, 2012; Applequist & Brown, 2008). The recognition of the multiple local legal systems that operate across the same territory is known as "legal pluralism" contrasting with legal monism that only recognises the states official legal systems (Santilli, 2012; Applequist & Brown, 2008). Hence the law has provisions on the collective rights of communities'

[68] A model law is created as a suggested pattern for law-makers in national governments to consider adopting as part of their domestic legislation

seeds and the right to collectively benefit from their use, rights to their innovations, practices, knowledge and technology and right to benefit collectively from their utilisation. In practice, these rights empower communities as they can prohibit access to their resources and knowledge, particularly in cases where access might deplete the integrity of their natural or cultural heritage (Biber-Klemm & Cottier, 2006; Applequist & Brown, 2008). The right to control access is strengthened with a right to receive at least 50% of the benefits derived from the commercial use of their resources or knowledge, and the state must channel those benefits to farmers' communities (Biber-Klemm & Cottier, 2006). The law also grants protection to varieties that may be identified without relying on the Distinctness, Uniformity and Stability (DUS) requirements. The OAU Model Law seems to replace the DUS requirements by the following concept: 'specific attributes identified by a community.' It is unclear, however, which attributes would be considered and how they would be determined. The absence of general criteria to establish eligibility for protection might lead to significant uncertainty and competing claims about ownership (Halewood, 2016; Applequist & Brown, 2008). Nonetheless, is the only that seeks to provide a comprehensive regime that includes not only the rights of farmers and communities but also the rights of commercial breeders.

The African model law has not been adopted in its original form by any country (Biber-Klemm & Cottier, 2006; Christinck & Tvedt, 2015). The Francophone members of the African Organisation for Intellectual Property (OAPI), have declined to join the Model Law in order to adhere to the Bangui Agreement, under the UPOV model of 1991 (Dutilleul & Bugnicourt, 2013), including Guinea Bissau. However some countries more than adopting the law as a whole, are integrating elements from this model law: Uganda's PVP law, for example, adopts elements of the African model law, as well as the national PVP laws from Ethiopia and Zambia (Christinck & Tvedt, 2015).

ECOWAS Seed Regulation Harmonization

The seed policy issues in the region were first stimulated by a 1998 FAO-sponsored conference in Abidjan targeting a generic review of seed policies and programs for Sub-Saharan Africa and resulted in the establishment of the African Seed Network (Rhonbarch, Minde, & Howard, 2003; ECOWAS/CORAF, 2015). Despite discussions over seed harmonisation going back to this conference, ECOWAS only adopted the harmonisation regulation in 2008. West Africa Harmonized Regulatory Framework is being implemented at the national level of ECOWAS member countries[69] focusing mainly on quality control, certification and variety release (ECOWAS/CORAF, 2015), having as core

[69] Benin, Nigeria, Togo, Burkina Faso, Ghana, Mali, Senegal, Cote d'Ivoire, Guinea, Gambia, Mauritania, Niger, Sierra Leone, Cape Verde, Guinea Bissau, Liberia and Chad

instrument to move forward the harmonization policy the West African Catalogue of Plant Species and Varieties (FAO, 2008; OECD, 2012; Halewood, 2016). The principal activities to implement this framework are: (i) Publication in official journal, (ii) Review of seed regulatory framework, (iii) Adaptation of procedure manuals and (iv) Capacity strengthening (ECOWAS/CORAF, 2015).

National Seed related Policy and Law

In Guinea Bissau, the Letter of Agricultural Development Policy (LPDA) and its plan of action which have been integrated into the National Agricultural Investment Program (PNIA), assigns to the agricultural sector a leading role in accelerating the growth and on creation of job opportunities for all. The Strategic and Operational Plan (2015-2025), formulated in March 2015 operationalizes the LPDA. At the seed level, the LPDA states that seeds and seedlings multiplication must be supported through professional organisations in the field. The following measures are foreseen under this policy: (i) Capacity building of national seed production institutions, (ii) Strengthening the capacity of private seed multipliers and seed multiplier farmers' networks for the production of quality seeds near production areas, (iii) Provision to accredited institutions of the necessary means to ensure the certification and quality control of seeds, (vi) Support to the organisation of quality seed distribution channels by producer organisations. On the whole, the focus of the Letter of Agricultural Development Policy (LPDA) is undoubtedly the formal seed sector with no reference nor recognition of farmers' rights as key providers of biodiversity and food.

The review of seed regulatory framework is the starting point to Guinea Bissau's regional integration in the seed harmonisation process (See above ECOWAS Seed Regulation Harmonization). Guinea Bissau has a provisional/draft "National Seed Policy" (2015), developed by the Ministry of Agriculture with FAO's support. The policy has the following main objectives: (i) provide Bissau-Guinean farmers with quality, timely, and affordable seed of sufficient quality, (ii) create conditions for increased use by farmers of quality seeds and (iii) strengthen the institutional and legal framework of the seed subsector. Two years have passed since the policy was drafted and there is still no progress towards a final version and promulgation. The "Ante Project of the Technical Regulation of Execution"[70] that establishes the technical regulations over certification and quality of seed is circulating among seed sector stakeholders in Guinea Bissau and is in the process of validation. However, it was not yet approved nor promulgated into the national law (FAO-MDRA, 2015).

[70] Draft document prepared by the Economic Commission for Western African States, Inter-State Standing Committee on Drought Control for the Sahel and the Western African Economic and Monetary Union

In chapter 6 it will be discussed in detail the extent to which these agreements and laws are being implemented in Guinea Bissau and the opportunities and challenges regarding farmers' rights under these different interrelated legal frameworks.

c. System of Property Rights

Section 2.2 addressed the nature of seed as good, in this section property rights systems concerning seeds are analysed. Ostrom and Cox (2010) propose as second-tier variables of analysis to look into property rights regimes as Private, Public, Common or Mixed. The first three categories follow the same definitions as the conventional typology while "mixed" category contains bundles of rights that can relate to both common and private property (Ostrom & Cox, 2010). In the context of this analysis, we will look at the property right regime by looking at both attributes of seeds: as artifacts and as ideas through each specific right. In this section, the nature of property rights in the seed system and how these are affected and governed by the regional and international agreements is analised.

Table 5. ***De jure*** **Property Rights Systems**[71]

Rights	Artifacts>Tangible > Seed as Physical >Material	Ideas>Intangible > Seed as Non Physical> Plant Genetic Resources
Access ***The right to access the agro-ecological system-land or facility and enjoy non-subtractive Benefits***	The same as *De facto rights*	**To *Ex situ* facilities:** International Gene-banks> only staff members and visitors, with formal permission are allowed to enter the gene-banks
Contribution ***The right to contribute to the content/idea of a seed***	N/A	Farmers in the lowland agro-ecology represent the majority of breeders in Guinea Bissau although also private and public institutions have the right to breeding activities (OAPI). However, there are no private breeders in the formal seed system in Guinea Bissau. Whereas in the public agricultural research system new varieties are mainly introduced by the international agricultural research system

[71] Under the Knwoledge as commons IAD framework "Extraction" is The right to obtain resource units or products of a resource system

		(e.g. Africa Rice Center; See Annex 3 Local Seed Varieties and Improved Varieties) through national agricultural research system
Extraction ***The right extract the resource unit seed as an idea from resources systems or facilities***	***In situ*** Within the ECOWAS Seed Harmonization Regulation exchange of seeds between farmers and seed saving becomes illegal as many landraces and varieties that farmers use may not meet the Distinctness, Uniformity and Stability (DUS) with demonstrated value for cultivation and use (VCU) criteria. Although Guinea Bissau did not yet transposed the agreement to national legislation, efforts towards this process are still being made with the support of international agencies (USAID, FAO) ***Ex situ*** Not applicable as accessions to international seed banks are done as removal of seeds as ideas.	***N/A***
Removal ***The right to remove seed as artifacts from the resource system or facility***	N/A	***In situ*** OAPI rules although not yet provisioned in related PVP domestic law, through the Bangui Agreement, that fully implements the UPOV 1991, applies automatically as the national law in each of the OAPI member States, including Guinea Bissau. *De facto* rights of withdrawal and use of the genetic resource to farmers communities can become removed according to *De jure* rights as provisioned by the revised Bangui Agreement if enforced

		In situ Under the Convention on Biological Diversity, states have sovereignty over their natural resources; Competent National Authorities grant users access to these resources. Two instruments shape the genetic material exchange between providers (states) and users (researchers, universities, industries) under this process Prior informed consent (PIC) and Mutually agreed terms (MAT)[72]. Under the Nagoya protocol States are considered to have sovereign rights over their biological resources, overruling the rights of indigenous peoples and small scale farmers. ***Ex situ (international level)*** International Seed Banks> Centres under the Multilateral system under the ITPGRFA make seeds available upon request under the Standard Material Transfer Agreement (SMTA) adopted by the ITPGRFA's Governing Body in 2006. The resources in the multilateral system are available to anyone who wants them under SMTA. Also under the ITPGRFA States also are considered to have sovereign rights over their biological resources
Management/Participation	***In situ*** This follows customary laws. See section 5.2.	***In situ*** This follows customary laws. See section 5.2.

[72] Prior informed consent (PIC): Is permission given by the Competent National Authority (CNA) of a country to an individual or institution seeking to obtain access to genetic resources, in line with an appropriate legal and institutional framework. Mutually agreed terms (MAT): Is an agreement reached between the providers of genetic resources and users on the conditions of access and use of the resources, and the benefits to be shared between both parties. (in Introduction to access and benefit-sharing, Convention on Biological Diversity: ABS)

The right to regulate internal use patterns and transform the resource system/facility by making improvements		***Ex situ*** ***International genebanks>*** right to regulate the internal use patterns of gene banks facilities as well as making improvements to facility under the ITPGRFA by the treaties' Governing Body which is composed of representatives of all Contracting Parties.
Exclusion ***The right to determine who will have access, contribution, and removal rights and how those rights may be transferred***	Although farmers have *de facto* rights to access, contribution, management however withdrawal in particular rights can be threatened through the ECOWAS seed regulation harmonisation process if implemented and enforced. The full set of rights that come jointly with withdrawal rights such as exchange sell, re-use of seeds can be seriously undermined	***In situ>***The Guinea Bissauan state has sovereignty over their natural resources, however given the absence of national law that establishes and defends farmers rights, international law such as the Bangui agreement can overtake national sovereignty as it leaves the Guinean State vulnerable to the establishing of PVP rights over landraces seeds, since other international treaties, once provisioned to the national law, could in fact protect farmers seed sovereignty (e.g. ITPGRFA, Nagoya Protocol), do not have the automatic character to become the national law in the same way as the Bangui Agreement.
Alienation ***The right to sell or lease extraction, management/participation, and exclusion rights***	N/A	***Ex situ:*** the treaties' Governing Body which is composed of representatives of all Contracting Parties

To a greater extent the most relevant rights with respect to seed do not lay in the bundles of property rights presented on the right column of this table. Hess and Ostrom (2003) in the context of knowledge, claim that these bundles of rights may be useful in rule setting for an organisation's digital repository. Similarly, these bundles of rights (e.g. access and exclusion) can be more useful when defining the rules concerning *ex situ* facilities such as gene-banks. Understanding property rights in bundles is extremely important, however, the most critical and relevant bundles to analyse in this context are Contribution, Extraction and Removal, along with bundles of rights associated with them. Specific examples of the coverage of rights include benefits arising from *contributions* to seed as ideas, the right to save, use, exchange, and sell *removed* seed artifacts from the resource system, as well as rights to participate in processes rules which might affect any of these rights.

For a Seed as an artifact, the removal right is currently attributed to a different set of groups according to customary rules. If ECOWAS *rules in form* are put in place and enforced, the removal right and the other attached rights will be challenged since farmers varieties might not conform to the newly established rules. While for seed as an "idea", rules under the Bangui agreement would directly affect removal rules with consequences towards farmers' rights. In effect, this would entail a shift from a common property regime towards private property regime. Section 6 will provide more detailed insights into the *rules in form* that are emerging and which are potentially challenging the *rules in use,* changing the current property rights system configuration.

5.2. Seed Governance *in use*

The Policy area of the governance system *in use* is the same as above: the environment, particularly in the context of biodiversity and farmers rights. The geographic range (GS2) considered here will be Bafatá region in Guinea-Bissau, where Resource System (see section 4.1), the lowland agro-ecological system, is situated. While the population subject to the system of governance considered (GS3) is the population of Bafatá Region (200,884 inhabitants in 2009[73]) whose livelihoods are dependent on the resource system under analysis. The following subsections will present in detail the following variables: GS5 – Rule-making organisations, GS6a *Rules in form*, GS6 – Rules-in-use and GS7 – Property-rights systems.

a. Actors and Rule Making Organisations

This sub-section presents a detailed description of the main actors present on the governance system *in use*. Since rulemaking organisations and actors overlap, this section will cover the core subsystem Actors (A). The second tier variables (**Table 6**) are included in all actors (A), particularly **for lowland farmers, the users** of the resource units (RU) and system (RS). Detailed data on all actors was not available therefore some variables are not covered. However a good picture of all actors is provided in detail in this section which is sufficient to inform the subsequent analysis.

Table 6. Second Tier Variables for Core Sub-systems: Actors

Actors
A1 – Number of relevant actors
A2 – Socioeconomic attributes
A3 – History or past experiences
A4 – Location
A5 – Leadership/entrepreneurship
A6 – Norms (trust-reciprocity)/social capital
A7 – Knowledge of SES/mental models
A8 – Importance of resource (dependence)
A9 – Technologies available

[73] http://www.stat-guinebissau.com/publicacao/Projeccao_demografica.pdf

Figure 8 below shows that the governance system *in use* is composed at the operational level mainly by the resource system (RS) users as main actors. At the collective choice level, there are users' organisations, community-based organisations such as APALCOF, Guiarroz, Proagri and Campossa and decentralised structures of the state. It is worth pointing that embed in this multi-level and scale structure are the traditional authorities which monitor resource system (RU) use and resolve conflicts following well-defined customary rules (Barry, 2007; Bruce, de Moura, & Tanner, 1992). (For a more detailed and in-depth discussion on the Governance Regime type (GS4) and Network structure (GS9) and Governance Structure see section 6.4). Some of these organisations are then supported at a constitutional level by international organisations through development projects and emergency seed aid. It is worth pointing that the levels of governance *in use* do not overlap entirely with the governance *in form* systems levels.

For example, collective level organisations in the governance system *in use*, are below the collective rule making organisations of the system *in form.* In terms of relevant actors it can be said that under this system is relatively small. At the operational level the main actor are the Users (1), and at the collective choice level there are Users Associations (APALCOF and Agro-Multipliers), INPA-Contuboel, Regional Directorate of Agriculture, Proagri, Guiarroz and Campossa (7). Hence, 8 (A1) is the total number of actors considered the most relevant actors in Bafatá region (A4) with respect to the lowland agro-ecological system (RS) under investigation. The agro-multipliers position in **Figure 8** suggests that these are at the operational level, despite being at collective choice level. This option is to allow differentiation of Agro-multipliers from the other collective choice level and to better exemplification of the seed flows and financial flows among actors. The norms (trust-reciprocity) and social capital (A6) aspects whenever found relevant are discussed across the board along this section for the different actors. It is worth pointing that overall, within the government system *in use*, these results suggest that there is a good level of trust within the users' community, as well between the different actors that constitute this system. Only in the context of Cereal Banks, results suggest that the rules which were introduced by the establishment of these cereal banks might be eroding norms of reciprocity which are standard practice amongst lowland farmers. There are very low levels of trust between the population and central government, particularly in rural areas. Conversely, schools and health centres are amongst the most trusted organisations in rural areas followed by religious organisations, the traditional authorities and NGOs (Barry, 2007).

Regarding the importance of resource (dependence) (A8), the Users - the lowland female farmers' - are without a doubt the most dependent on the resource system (RS) since they are engaged in processes of harvesting, producing, and consuming resource units (RU) - seeds. However, for local NGOs and Users Associations members, the resource systems is intimately related to their livelihoods.

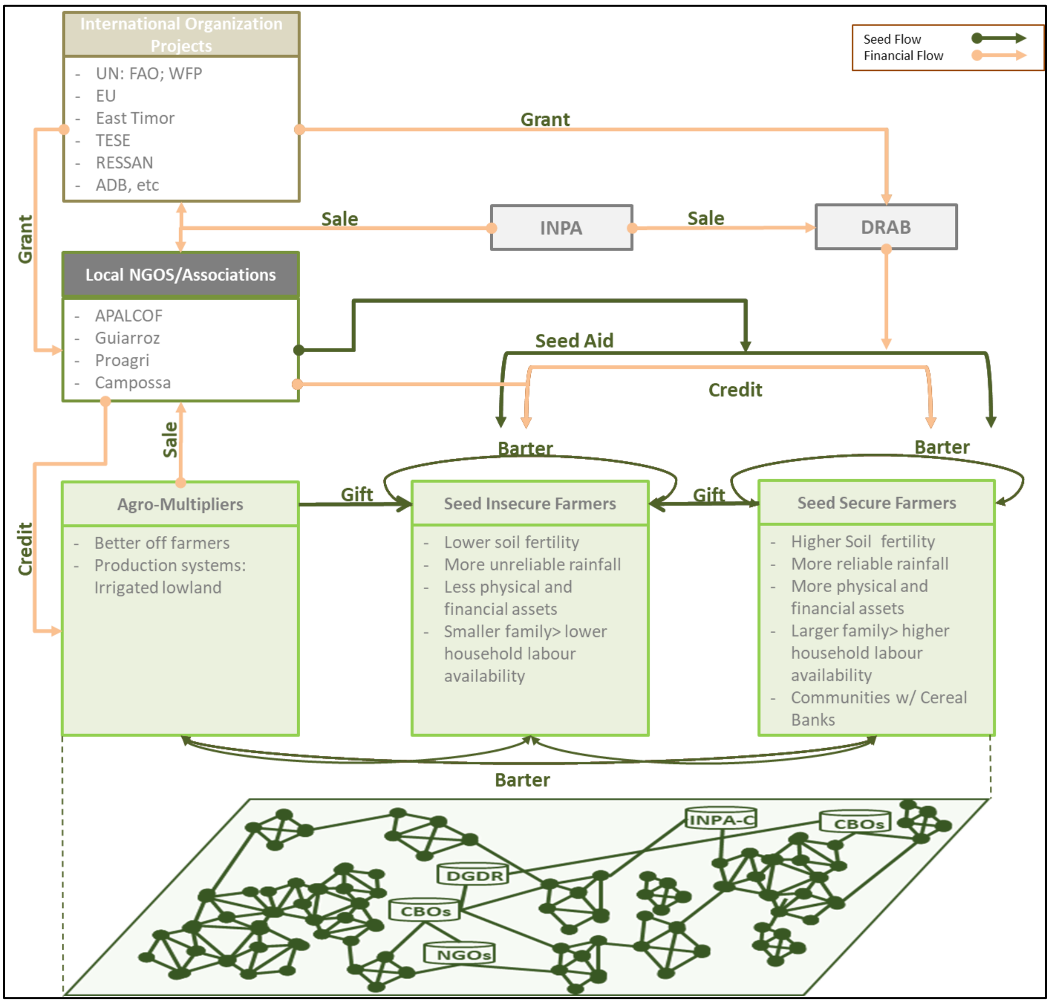

Figure 8. Overview of Rice Formal and Informal Seed System in Bafata Region

The remainder of the section will describe these actors, the relation between them and the flows of resources. (N.B. details on Actors at the Constitutional Levels: Appendix I Meta-constitutional, constitutional and Collective Actors and Rule Making Organisations)

Bafatá Regional Directorate of Agriculture is responsible for implementing the national policies at the regional level namely in the context of agricultural research and extension systems. In this context, its role is to supervise and coordinate research and extension activities carried out by different actors, particularly development projects and NGOs. However, due to the lack of funding and other problems, it is not able to perform its mandate fully. As a consequence, NGOs and other development organisation are implementing extension activities with limited political guidance and government support. Organisations working in the rice sector adopt their own approaches, with very little connection or support to research systems, input supply, credit or trading that provide services to rice producers. Despite of the difficulties in promoting policies and approaches for the agricultural research and extension systems, in a more practical level, the Regional Directorate is the entity responsible for channelling improved varieties produced by INPA's research stations or other sources to rice farmers.

The **National Institute for Agricultural Research** (INPA) has the leading mandate for agricultural research in Guinea Bissau. Despite its broad mandate, INPA has very meagre means to comply with it fully. INPA's mandate focus on six main areas: Agricultural research, Production of plant and animal material, Dissemination of new technologies, Training in the agricultural field, Dissemination of technical and scientific information and Service delivery. The headquarters are in Bissau and four centres for agricultural research according to different agro-ecological areas and crops:

- The Research Centre Contuboel, located 180 km from Bissau to the east is specialised in upland and irrigated lowlands rice. It has a seed laboratory and a soil laboratory, although they are inoperational;
- The Research Centre Caboxanque specialised in mangrove rice located south of country 280 km from Bissau;
- The Research Centre Quebo located 206 km from Bissau to the south of the country, specialising in fruit growing and horticulture;
- Zootechnical Centre of Bisorá is specialised in animal production and situated in the north of the country 80 km from Bissau.

Due to civil war and continued political instability, most of these centres are depleted from human and physical capital. INPA currently faces a severe shortage of human resources in all aspects, both quantity, quality and diversity. In 2014, INPA had only 21 technicians, compared to 42 in 1995, there was a loss of 21 technicians. Most managing positions are now working in development-oriented institutions that offer more attractive salary conditions. Currently, INPA has more than 563 ha of land of which only 60 ha is developed or occupied which results in an occupancy rate of 1%. Despite the potential, its performance is not satisfactory due to the lack of material and financial resources for its normal functioning. Indeed, seed storage units at Contuboel and Caboxanque research centres are currently not operational. Also, the Soil and Seed Laboratories in Contuboel and Livestock Health laboratory in Bisorá are not operational due to lack of electricity and necessary materials (FAO-MDRA, 2015; UE, 2015). The state of degradation and inoperation of these centres results in low level of scientific production, innovation and diffusion of technologies, particularly to rice farmers.

Despite not having the resources to comply with its mandate, INPA is engaged in activities that fall out of it. Since INPA often sells their seed production (not pre-base or base) directly to projects or NGOs to meet the needs of farmers for food production, which is partly a response to the absence of a formal market. However, it is also argued that INPA's role as seed producer results in unfair competition and is actually the one of the reasons behind the virtually inexistence of a private seed sector.

A formal seed sector, beyond the government agricultural research system, has yet to develop in Bafatá region, as most farmers in the lowland agro-ecological system produce their own rice seed year after year or rely on other farmers to obtain seed. There are virtually no formal **producers, breeders, traders and agro-processors.**

Seed production in the formal seed supply system, generally requires a sequential process, which is vertically organized. It begins with a pre-basic seed, issued from breeder seed supplied by a national or international research system. These institutions often sell breeders and foundation seed to seed producers with technical advice on how to multiply foundation seed into the commercial seed (Setimela, Monyo, & Bänziger, 2004). Seed production in the formal seed sector goes through several testing procedures in order to ensure that quality is maintained over time. Also, seed legislation is in place stipulating the quality standards for each crop, namely rice. The implementation of testing, field inspection and quality control procedures gives credibility to the marketed product (FAO, 2001) [74]. Usually public or private sector agencies are responsible for producing and marketing seeds provided by plant breeders, and there are other organisations responsible for certifying and controlling quality. These are broadly the main characteristics of seed production in the formal sector.

However, the majority of seed production is actually in the informal seed supply system, notwithstanding INPA's informal role on seed production. Informal in the sense that INPA is not producing pre-base or base seeds as defined by its mandate, therefore its seed production cannot be labelled as formal. There are few farmers associations specialised in seed production and multiplication that provide seeds to other farmers, through credit (if the village has a cereal bank),

[74] http://www.fao.org/docrep/005/y2722e/y2722e0d.htm

exchange and gift. INPA's Contuboel station is the sole seed producer in the formal sector as it multiplies foundation seed from breeder's seed provided by International Agricultural Research Centers (IARCs) breeding programs and supports these agro-multipliers associations. Nevertheless, Contuboel station does not have sufficient resources (human and financial) and processes to guarantee an adequate production of foundation seed. Moreover, there are no regulations or formal organisations that are responsible for certifying seed and controlling its quality. The only seed producer from the formal sector, INPA, does it informally since it is outside its mandate (FAO-MDRA, 2015; EU, 2015).

Seed markets are characterized by different **levels of traders as follows**: i) Large traders: source and/or sell to larger and often more distant areas (cities or abroad) as well as to smaller traders; ii) Medium size traders: obtain seed directly from farmers, obtain grain from collectors or grain millers, re-supply collectors and farmers directly with seed during shortage; iii) Collectors: usually serve 3 to 5 villages and link farmers and bigger merchants; and, iv) Farmers: sell their own production as seed directly to neighbours, at local markets themselves, up to collectors and to mid-level, medium-sized traders (CIAT, DEV, & CRS, 2013). A well-developed and mature seed market would involve the presence of most of these actors linked in a close-knit network. However, in Bafatá region there are virtually no formal seed traders for the lowland rice system, making the seed supply system predominantly informal, where farmer-to-farmer exchanges and farmer self-saved seeds are critical components particularly in the lowland farming systems. A critical constraint to agricultural productivity of in Guinea Bissau is the access to inputs. There are currently no support services to agricultural production, particularly in relation to the input supply system where formal **Agrodealers** provide inputs such as pesticides, herbicides, fertilizers and other agricultural materials. Most of these are difficult to access as they can only be obtained in Senegal or Gambia with the high costs of transportation that their acquisition entail (Djata et al., 2003). Most of fertilizer source used by lowland female farmers is provided by INPA, again a service that it provides outside its mandate.

With respect to **agro-processing**, the grinding by hand using the traditional pestle is the most common means of processing of rice in Guinea Bissau. Back in the period where there were surpluses in rice production (1940 - 1955) some Portuguese business houses operated large units husking rice paddy bought by farmers and small traders using a system of production credit in the form of supplies of consumption goods (brandy, tobacco, clothing, small agricultural tools) as well as cash, transformed and sold rice traders and institutions in the capital city with small quantities exported. However, these units stopped working when supplies started to become scarce during the 60s. More recently, a rice husking unit was established in the agro-industrial complex of Xayanga. However, this unit is not currently operating due to poor location, supply problems and mismanagement (Spencer, Dunstan, & Djata, 2008). After independence, small scale rice huskers were distributed throughout the country by government and NGO projects, the last being the KR2 project. This project provided huskers a capacity of 450-500 kg/hour and the SB10D with a capacity of 950-1000 kg/hour of paddy rice at prices subsidized 6.65 million FCFA for SATAKE SB 10L (30% subsidy). Some units were supplied before the project came to an end due to the military conflict that erupted in 1998. Currently, there are very few rice huskers operating in the country. Most of them provide services for consumers and small businesses, however the large majority of them are damaged due to poor maintenance caused by parts shortages and inefficient operation. The Guinea Bissau experience with agro processing of rice can therefore be classified as weak (Spencer et al., 2008). The scant agro-processing activity in Guinea Bissau in spite of the introduction of many rice transformation units is a result of the following: (i) Formal agro-processing and transformation enterprises do not exist because of the lack of economic incentives; (ii) Lack of coordination on import machinery adapted to country's context (Djata et al., 2003). Consequently, farmers do not possess the economic resources to buy, maintain and to make a profitable use of the machinery as they are very expensive to maintain and there is not a consistent supply of spare parts in the main cities and much less in areas of Contuboel and Bafatá. In conclusion, there are no formal agro-processers, the majority of the operational agro-processing machinery in Bafatá region, are the ones provided through the Decentralized Program for Food and Nutritional Security in Guiné-Bissau [75] promoted by IMVF NGO, in its beneficiary villages and some more well off farmers who have their own machinery and rent it to friends and neighbours.

Users: Lowland Rice Farmers

The largest community of users/actors of the Seed Socio-ecological system is Bafatá Region is without a doubt the **female rice farmers** working in the lowland agro-ecological system. The data used in the analysis below was collected through a survey to a representative sample of farmers of the Contuboel sector[76] (for more detail on data and sampling strategy see Chapter 1). These households represent the users, a particular type of actor, the one that is simultaneously engaged in the processes of harvesting, producing and consuming resource units (McGinnis & Ostrom, 2014).

[75] See below details on this IMVF NGO Project

[76] A total of 351 households were interviewed between February and March 2015, immediately after the harvest period and before the sowing period of the following rainy season.

In line with other countries in West Africa (e.g. Gambia, Côte d'Ivoire, Guinea Conakry) the majority of lowland farmers are female (98%). The average age is 32 years old, and most farmers did not have any form of formal or religious education, only 9% of farmers went to primary school.

The gender-specific incomes and asset holdings are consistently lower on average. The household level yearly income is 356 945 FCFA (600 USD) whereas female owned and managed income is on average 35 865 FCFA (60 USD), one-tenth of households reflecting the residual involvement of women in cash crop production. The main reason for this dramatic difference between man and women is the fact that the two most profitable agricultural activities, cashew nut and livestock, are virtually dominated by man. Non-agricultural income follows the same pattern, whereas household's total non-agricultural income is on average 211 117 FCFA (354 USD) and female non agriculture income only 2 219 FCFA (4 USD). Interestingly, a livestock gender gap, on the other hand, is not so evident, where total household livestock value is 1 533 624 FCFA (2578 USD) from which female owned livestock value represents approximately 40% of the total livestock of the household (604 894 FCFA/1.017 USD). It is worth pointing that these results are particularly relevant since the household structure is rather equilibrated in terms of the average number of female and male adults, with 3.1 and 2.9, respectively.

In terms of farm characteristics, the area owned is approximately 1 hectare per household and the number of plots is 2.74. The area and number of plots planted was less than the area and plots owned, respectively. Common reasons for non-planting the whole area owned was to leave land fallow or due to sickness or death of the plot manager or some family member. Due to pre-harvest losses, also the land harvested is inferior to the one planted.

Mechanisation is very low for lowland female farmers with only 2% having access to tractors to plough their land. On the other hand, "Charrua" (plough) drawn by cows is more widely used with 51% of farmers reporting their use. The use of inputs beyond seeds is virtually inexistent, merely 4% of farmers use fertiliser and none has reported using herbicides or pesticides.

Concerning soil quality 24% and 73% consider their soil of rich and very rich quality, while very few have the perception of poor and very poor soil quality. With respect to land tenure, most farmers have inherited, or land has been donated to them. With respect to formal ownership, 95% assert that land is owned by them however virtually none has a land title. This is not reflected on farmers perception of tenure security since only 15% and 27% perceive high and medium risk of expropriation or land being removed in the next five years, respectively. This is an indicator on farmers trust on customarily defined rights over land.

Overall, this data shows us that the users in this socio-ecological system, are women who deal with labour intensive farming, are in a disadvantaged position regarding income and assets and have a very limited range of technologies at their disposal. These technologies ranging from irrigation, which is limited to very few villages associations in the region, to fertiliser, herbicide and mechanisation, are virtually inaccessible to women working in the lowland agro-ecological systems.

Cereal Banks Organisations

Villages that have **Cereal Banks** (always including a seed bank) were created with the objective to promote seed security and increased food security. Cereal banks associations members in the context of a training reported[77] the key positive outcomes of the implementation cereal banks across the region. Some of these positive aspects were focused on how villages with no cereal banks wasted a lot of time looking for seeds and work material, even facing the risk of not finding good quality seeds for sowing, while villages with seed banks have everything at hand without a great effort and no need for money. Also village cereal banks allowed people with no money available to access seed because they can borrow and pay the later in the form of seeds. Finally, it was also claimed that quality of seeds provided by the cereal banks is more trustworthy when compared to the one of sold in the free market, where farmers can be cheated buying seeds out of expiry date with no germination capacity. Despite the perfect picture provided by cereal banks members' testimonies, it is worth pointing that it was reported by few farmers and organisations interviewed, that not all cereal banks are perfectly functioning. Aspects such as trust in the governing bodies' members and leadership are said to affect members' engagement and participation, namely by reducing the amount of seed stored in these banks.

Some of these seed banks were promoted by International NGO's. Promoted by a **Portuguese NGO ISU from 2011 to 2013, "Bantal Demobe"[78]** was a project with significant impact on rice's seed supply system in Bafatá region. Its goal was reinforcing production capacities to promote food sovereignty and environmental sustainability. Amongst many activities, this project promoted the creation of community cereal banks and capacity building for transformation and commercialisation of local products. In the same stance of the previous projects the cereal banks created in this project's context

[77] News article from IMVF NGO providing testimonies of farmers in the context of a traning on cereal bank management http://www.imvf.org/index.php?noticia=1324
[78] Arise Peasants, translation from Fula language from Guinea Bissau

were aimed at increasing food security. Covering seven regions in Guinea Bissau, including Bafatá, the "Decentralized Program for Food and Nutritional Security" promoted by the **Portuguese NGO Instituto Marques de Valle Flor,** had two phases. The first phase (2009-2011) amongst other activities, they promoted agro-processing technologies, storage facilities and commercialisation of agricultural products, namely rice. The second phase of the program (2011-2014) was a continuation of the activities of the first phase, expanding the access and profitability of transformation and storage technologies, also focusing on support to rice, vegetables and fruit production and promoting access to inputs and services to support these agricultural productions. The beneficiary villages always have an association in charge of the cereal banks, mills and threshing machinery which they rent to associates in the village and farmers outside the villages. These villages constitute major seed exchange platforms as many people come with different varieties from outside to make use of the agro-processing machinery which enables the exchange of information over rice varieties thus enabling exchange and gift among rice farmers.

Additionally, these associations also perform as informal agro-processors as they provide services to rice farmers who can not afford them. According to the members of one of the beneficiary association, the cereal bank contributed directly to reducing food insecurity in the community, particularly with respect to rice. Both these programs were funded by the European Union and Camões Institute of Cooperation and Language.

The region is also characterised by a dynamic civil society with many **non-governmental organisations and farmers' community-based organisations working the lowland agro-ecological system**.

Users Organisations

APALCOF was established in 1990 by rural women of the Bafatá region to improve their living conditions, to address gender inequality in agricultural programs and reduce poverty and workload among rural women. APALCOF is a federation of 29 rural women's associations having approximately 2.500 members. When first established, APALCOF's main activities were market gardening and vegetable farming. In 2002, with the support of the World Food Program, they started the development of rice cultivation and the creation of a Cereal Bank. The association has some services to support its members that range from technical assistance and training on their main crop domains (vegetable farming and lowland rice) to providing seed credit from its Cereal Bank placed in the Village of Contuboel. From APALCOF Cereal Bank each member can have access to 40 to 50 kg of seeds and grain for credit, and after the harvest, they repay with an interest of 20%. In 2012, INPA sold APALCOF

750kg of rice seeds from many varieties that were multiplied and subsequently made accessible to their associated farmers, through its Cereal Bank. Regarding rice production, their associates work only in the lowland rice production systems. Two of their member associations, the agro-multipliers, have irrigation infrastructures (e.g. motor-pumps, well-designed diques) thus unlike the other 27 member association they get two harvests from the same area, the dry and rainy season harvests, respectively. These two communities, as net seed suppliers, can provide seed to other farmers in the forms of gift or barter and less frequently to sell in the context of specific development projects, as described above. APALCOF associates have been changing their rice varieties portfolio through the years towards “drought-escaping” rice, that is to say, varieties that can grow over a shorter cycle. Before 2002 most of their associates planted local varieties namely Rasta, Bom Dia and Ela Djala. Around 2002 different varieties were more popular such as Sab 12, an improved Chinese variety introduced by INPA and Bani Malu, a local variety. Bani Malu, Sab 12, Nerica L19 and Sahel are currently the most popular varieties amid their farmers. According to APALCOF, the reason behind the adoption of shorter cycle varieties are smaller rainy seasons, increased frequency and intensity of rain and longer dry spells, which together have been affecting their rice variety portfolio.

Established in 1993 by former DEPA Staff, **Guiarroz is a local NGO** working with farmers in the rice and vegetable farming sectors in Bafatá region. They support 188 villages from the sectors of Sonaco, Gabu and Contuboel, in a wide range of activities. Particularly training farmers in modern rice farming techniques, providing rural credit to buy equipment’s, livestock and commerce activities, assist farmers with on-farm processing equipment, supporting the establishment Community Cereal Banks and the rehabilitation of lowland irrigation infrastructures. Most of these activities are funded by multi and bilateral donors in the context of development projects, where Guiarroz usually partners with international NGOs.

PROAGRI is a Development NGO created in 2006, also by a former DEPA collaborator, its work focus on livestock, agriculture and forestry sub-sectors development. PROAGRI provides support to 15 associations’ covering 719 farmers, mostly women from Bafatá region. Processing and conservation of agricultural products, capacity building and training, the rehabilitation of lowland rice infra-structures, vegetable production and the construction of Cereal Banks, are some of the areas of expertise with which PROAGRI supports its beneficiaries. PROAGRI performs as an implementing partner of large sectorial projects funded by multilateral donors, namely World Bank, FAO and African Development Bank. Also implements small projects as a promoter funded by SNV and Swiss Aid. **Campossa** is local rice producers’ organisation formed in Bafatá in 1991. By using irrigation, they produce two harvests of rice a year instead of the typical single harvest. However, due to internal governance problems is no longer operating.

Villages with Irrigation Associations

In May 2009, FAO promoted a two-year project in partnership with the World Bank funded by the EU Food Facility with the objective of supporting the government of Guinea Bissau to deal with the high food prices. This €3 million project supported 25 000 vulnerable farmers' with fertilisers, seeds, tools and capacity building. It also funded the rehabilitation of agricultural infrastructures, namely rice fields and market garden plots. Additionally, in cooperation with the Ministry of Agriculture and INPA, FAO trained 50 farmers in seed multiplication activities with the goal of strengthening their understanding of the production cycle, ranging from the supply of seed stocks to the marketing of seeds. In this context, in 2010 a training in seed production was conducted by INPA to: i) 20 farmers from two villages (Contuboel and Sintchã Marcel) and ii) 30 farmers members of APALCOF, from 5 different villages, however only 2 farmer's groups (Sintchã Ioba and Contuboel villages) managed to obtain the funds to co-finance the construction of irrigation infrastructures, a necessary condition for seeds production.

The first group of farmers, with the support of INPA, was formalised into the **Association of Agro-multipliers of Contuboel**. This association was created in 2010; this association was initially formed by 20 farmers (15 Women and 5 Men). With the new memberships in 2014, the association had 50 rice farmers' members (30 Women and 20 Men). One of the constraints to the enlargement of the number of associates is the availability of irrigated fields in Contuboel. The reason behind their selection by INPA was because these farmers had a history of collaboration with DEPA (the former INPA) and were also considered the most knowledgeable in seed production in the area. Therefore this group, closely linked to INPA, was also the one selected to take part in the on-station variety trials promoted by INPA with the support of the Africa Rice Centre.

In 2012, after the PVS trial at INPA station[79], these farmers were offered NERICA L19 by INPA for multiplication. Even though the ultimate goal of the FAO project was for these agro-multipliers to act as small scale seed producers and traders selling their seeds directly to neighbours, at local markets themselves or to mid-level traders. However, since their creation, the economic situation of the country has worsened as a result of the political instability, further undermining the already vulnerable livelihoods and living conditions of most farmers in Guinea Bissau, making their ability to pay for seeds

[79] see **Appendix IV** for details on PVP process

very low. As a result, most of seeds surplus produced by these farmers are offered within their social networks of kin and friends, on their villages and from other villages, or sold to INPA or NGOs/International Organisations in the context of projects. This association faces many constraints, namely the quota (3€/associate/year) amount collected from their associates is clearly insufficient to cover costs with fertiliser and fuel. To help covering these costs, INPA supports them with fuel and fertilisers and they barter by the money equivalent with seeds plus a 10% interest. Also in 2013, they received extra support from UEMOA.

The two villages associations of members of **APALCOF** were trained as agro multipliers in 2010 in the context of FAO's project. They also reported not being able to sell seeds to other farmers due to their inability to pay for seeds. Like the Agro-multipliers Association of Contuboel, most of these farmers' seed surplus is offered to other farmers for the same reasons and contexts expressed above.

In 2013, the Special Representative of the UN Secretary-General (SRSG) to Guinea-Bissau, José Ramos Horta "sponsored" the creation of an East Timor delegation of their Development Cooperation Agency in Guinea Bissau. Amongst the activities supported was the distribution of free seed to vulnerable farmers in 2013. APALCOF was part of one of these projects and brought demand and supply together: the agency was looking for seeds to buy, and the APALCOFE agro-multipliers had seeds to sell. The rice seeds were sold to the agency and APALCOF was responsible to deliver them for free to other associated farmers. This operation was a one-time event where the agro multipliers had a buyer for their seeds.

b. Rules in use

This section focuses on *rules in use* at the intermediate collective and operational level. It describes the informal institutions around seeds, bundles of rules underlying seed sovereignty rights: such as to save, replant, breed and share seeds, and their right to participate in decision-making processes regarding rules and laws that regulate their access and use (Kloppenburg, 2013).

INPA

INPA in Contuboel does not have resources to comply with its mandate, namely as a breeder, but on the other hand, is engaged in activities that fall out it. INPA often sells their seed production directly to projects or NGOs to meet farmers' needs, which is an activity that falls out of their mandate. Despite being a response to the absence of a formal market, INPA's role as commercial seed producer, can also result in unfair competition that might inhibit the agro-multipliers to become formal commercial-oriented seed producers. It was also reported that INPA Contuboel's collaborators sell seed directly to farmers, although it's not clear the circumstances of these transactions: do they do it as privately as farmers, are they "illegally" selling INPA's seeds production without INPA's acknowledgement or are they doing it "legally" as being part of INPA's "informal" mandate. Although INPA does not have the *De Jure* right to sell seeds evidence suggests as it has a *de facto* right.

Users: Lowland Rice Farmers

With respect **to rules related to save and replant seed, these** are intimately related with tenure arrangements of the lowland agro-ecological systems. The resource system in Guinea Bissau is intimately related with the social organisation of the *tabanca*[80], a village that is formed by one or several *morança* which are smaller areas usually defined by extended family. Tenure arrangements of lowland fields are shaped by the organisational structures of the tabanca. The *morança*[81] usually has control over a collective field from which production is used for the extended family use according to certain rules. While the *fogão*, approximately a nuclear family[82], have their own individual fields for their specific consumption *(*Bruce et al., 1992; Oliveira, Havik, & Schiefer, 1996*)*. For the *morança* collective field, the first wife of the *morança* head has the responsibility for the organisation of the work, control of production for consumption and seed reserves. The seeds are supplied by the oldest female of the *morança*, although each *fogão*, has its own seed reserves. In *fogão* collective fields, the mother of the household head, the stepmother, if she is older, or the female head (in case there are no men present), will be responsible for everything that concerns the collective production of women at the household level (Oliveira et al, 1996). Also within the *fogão* there are individual production units, usually each adult female (wife(s) of the head of household or mother of head of household) member of the household is formally entitled to a land plot to produce for their own consumption. Although *fogão* members might make up separate production units in their own right, however labour and food exchanges are common at all levels (Bruce et al, 1992). Seeding is mainly done by women, guided by the older woman of the household, who has the responsibility to choose the cultivation sites according to the vegetative cycle of each of the varieties that they intend to produce and the characteristics of the soils. During the harvest, women first cut the larger panicles, selecting the best

[80] A Village that is formed by one or several *moranças*
[81] the term *morança* is most often used to distinguish between the residential areas of the different extended families or lineages in each *tabanca* (village formed by one or more moranças).
[82] Within *morança*, the basic organisational unit is the fogão (stove), which approximates to a nuclear family of two or more generations sharing the same cooking place.

for use in the next sowing season, the remainder of the harvest is saved for own consumption (Oliveira et al., 1996). The focus groups and interviews held with different farmers in different villages showed that these rules have not changed since the research period of the referenced literature.

The ***rules in use*** **that shape seed exchange** among farmers depend ultimately on the end use for which these seeds are being requested. Farmer's that support other farmers through Gift are usually seed secure farmers that tend to have better soil quality, such as the *basfond* within Geba river basin, have larger families, and more resources to contract people to work if the family is small. Conversely, seed receivers usually have worse soil quality, transition *basfond* (farther of the Geba River Bassin), smaller families or fewer resources to contract people to work if the family is small, and are people who were typically not able to keep their stock for their sowing needs. This usually happens as a result of the inability of buying rice grain in the "hunger period" and having no option but to eat their saved seed. The relationship among people who offer/receive is seeds is usually classified as family or friends. Also exchanges occur predominantly among the same ethnic group, though less frequently with friends and from other ethnic groups. With respect to location, seed trades occur within village or outside village depending on whether the reason for the lack of seed affects the whole village (common shock) or is just individual/household level (idiosyncratic shock). Regarding exchanges, these occur almost exclusively between people of the same sex, which means that in the case of *basfond* agro-ecological system seed exchange always occurs between women. The quantities exchanged in the context of seeds gifts are usually around (5-10 Kg), and the type of seed offered/received is either new or some variety that recipient farmer was already using, it depends on the type of seed that the person offering has available. Farmers' motivation to offer seed is explicitly to help others with the implicit motivation of reciprocity expectations in the future while farmers' motivation to receive is usually to satisfy its sowing needs. In terms of seed barter, in the same way as in gift exchanges the relationship among people who barter seeds are family most predominantly and also friends, from the same ethnic group and less frequently different ethnic groups. With respect to location, firstly they look in the same village, if there is no seed to exchange they go out to other proximate villages. If they know there's a good variety farther, farmers will go there to exchange. The quantities exchanged through barter are usually larger than the typical gift ranging between 10 and 50Kg. Farmers motivation to barter seed for seed is usually to obtain a new variety, usually from a local variety but with a trait that is valuable for the farmer. Seed exchanges underlying gifts driven by necessity, usually under some heterogeneity between farmers either regarding assets, agro-ecological conditions or technology (irrigation)/facility (seed banks).

Rules in use **underlying the right to breeding** differ from the ones regarding seed exchange. **Seed selection and crop diversity** management is predominantly done by women in the lowland agricultural system. As already mentioned above, within the household, is usually the older women, the ones with greater knowledge and control over the seeding process, seed selection and storage. Older women are the guardians of traditional knowledge associated with lowland rice in the east region of Guinea Bissau. However, it is worth pointing that younger women are reportedly losing their interest in rice farming and so the knowledge around selection and diversity management is thought to be slowly disappearing. These rules attribute to female lowland farmers the *de facto* right to varietal breeding in Guinea Bissau, and these rights are guaranteed by the *rules in use.*

Cereal Banks Organisations

Usually cereal banks are managed by village associations that can be either formal or informal. These banks provide seeds through credit to associate farmers with an interest rate ranging from 10% (Bantal Remobe) to 20% (APALCOF), to be paid in the form of seeds. Usually, farmers borrow before the rainy season a few bags, and after the harvest, they pay back the same amount of bags borrowed with the added amount of interest. The seed obtained in the form of interest is distributed among the association board and the remainder seeds are available to borrow to farmers in need.

In the context of lowland rice, farmer to farmer mode of exchange is reciprocity, mainly through direct barter (immediate exchange) and in the form of gift exchange where a return is eventually expected (delayed exchange). However, in villages with cereal banks, the availability of seeds in the form of credit seem to lessen these norms of reciprocity, as farmers in villages with seed banks are less prone to offer seeds and exchange seeds. Notwithstanding, farmers facing seed insecurity come to these villages looking to obtain seeds in the form of credit.

Although not yet approved, seed banks are a critical policy measure under the National Seed Policy, to promote seed security. However, the function of seed bank so far has been focusing on seed as agricultural input and less as possible local *ex situ* conservation facilities Moreover, while the policy recognises seed banks as artifact facilities, it ignores their potential role as idea facilities. Hence, there is a *de facto* right to perform as artifact facility although in reality, it has a *de jure* right of both idea and artifact facility. Finally, it is worth noting that the creation of seed/cereal banks in the context of development projects, having food security has main goal, seem to have had an effect on rules regarding the exchange of seeds. In particular, cultural norms of reciprocity to have become eroded by the establishment of these new institutions, as reported in some interviews held with farmers.

Villages with Irrigation Associations

Seeds provided by agro-multipliers are predominantly in the form of a gift. Farmers that seek the agro-multipliers for seeds are the ones that weren't able to save seeds for the next season or for some reason lost their seeds. Farmers that are not able to stock seeds are farmers that do not produce in sufficient quantity to satisfy both their family food consumption needs and make seeds stock for the next cropping season. The inability to produce in quantity is mainly a result of one of, or a combination of the following factors: i) insufficient rain that lowers the productivity, ii) low soil quality, iii) small family number to work on rice production, iv) lack of resources (e.g. money, livestock) to enable hiring additional labour to work on the fields. Another reason for some farmers to ask for the seed to agro-multipliers is a bad combination of the timing of seedling together with poor, heavy or erratic rainfall that results in a partial or complete crop loss. Although the initial purpose of these groups was to produce seed of quality as input to farmers, they report to never sell seed to farmers that are in hardship claiming "you cannot deny seed to a farmer in need". The chief buyers of their seed are international organisations and NGOs in the context of development projects.

In sum, lowland agro-ecological communities have *de facto* rights regarding seeds, rights related to seed as an artifact and as well as an idea, notably the right to save, replant, breed and share seeds. However, as discussed in more detailed in section 5.2, rules establishing rights to participate in decision-making processes regarding rules and laws that regulate their access and use as well to fair and equitable sharing of benefits arising from their contributions are breeders, do not seem in place. It is also important to notice the way development projects, which through activities regarding seed aid, infrastructures such as irrigation and cereal banks, might be slowly changing the rules. Overall, female farmers in lowland agro-ecological systems have only limited seed sovereignty, since all bundles of rights underlying sovereignty are not being enjoyed.

c. The system of Property Rights

In the same way as the property rights analysis above, I will look at the property right regime by looking at both attributes of seeds: as artifacts and as ideas through each specific right.

Table 7. *De facto* Default Property Rights System[83]

Rights	Artifacts>Tangible > Seed as Physical >Material	Ideas>Intangible > Seed as Non Physical> Plant Genetic Resources
Access ***The right to access the agro-ecological system-land or facility and enjoy non-subtractive Benefits***	Farmers who have exclusion rights to the land have the right to deny access to their land, deny access to the resource system. Female farmers in the lowland agro-ecological systems own, rent and borrow the land following the customary tenure system rules. Usually all members of the village can have access to the land. Farmers within a village which usually work in the same *basfond* (a larger area of land composed by several plots) have access to the land of other farmers in the village.	The same as on the right. Although farmers from other villages and communities can be provided access to remove "non-subtractive benefits": seed as an idea
Contribution ***The right to contribute to the content/idea of a seed***	N/A	Farmers have the *de facto* right to breeding: Farmers in the lowland agro-ecology represent the majority of breeders in Guinea Bissau. Within the informal seed system using indigenous strategies farmers improve the quality and quantity of seed with full breeding activities Breeders in the formal seed system> Private: there are no private breeders in the formal seed system in Guinea Bissau for lowland rice Public: new varieties are mainly introduced by the international agricultural research

[83] Under the Knwoledge as commons IAD framework "Extraction" is The right to obtain resource units or products of a resource system

		system through national agricultural research system produce in Guinea Bissau.
Extraction ***The right extract the resource unit seed as an idea from resources systems or facilities***	N/A	The idea, the intangible component of a seed - the germplasm – not only is extremely difficult to excluding potential beneficiaries, as well as excludability is outside informal institutions ruling the access to germplasm. Seed exchange is shaped by cultural norms of reciprocity. The gift and exchange of seeds as genetic material is crystalized in farmer's social norms. (See *Rules in use* at an Operational Level). Moreover seed saving, exchanging, using and selling are part of the cultural repertoire of rural communities – operationalised in customary practices that go beyond national borders. Rice farmers' communities in Guinea Bissau and neighbouring countries have long lasting *de facto* rights over biological diversity. Notwithstanding *de jure rights* that either recognize farmers or the nation state as sovereign proprietors over biological diversity, the lack of transposition of these provisions established by international treaties in the national law results there is no protection on *'de facto''* farmers rights in a *'de jure'* manner. This gives leeway to: bioprospecting without adequate benefit sharing and/or illegal appropriation of PVP rights over farmers' PGR.
Removal ***The right to remove seed as artifacts***	Individual production units> Each adult female (wife(s) of the head of household or mother of head of household) member of the household (*fogão*[84]) is usually	*N/A*

[84] the *fogão*: approximately a nuclear family[84], own individual fields for their own specific consumption

from the resource system or facility	formally entitled to a land plot to produce for their consumption. Although *fogão* members might make up separate production units in their right, labour and food exchanges are common at all levels. These farmers also have rights to another bundle of rights that come jointly with extraction rights: the right to seed saving, exchanging, using, selecting and selling the seed that they extract from the lowland agro-ecological system. Collective *Fogão* or *Morança*[85] rice field or on fields cultivated by members of age-sets or youth groups>in this cases the extraction rights goes to the group as a whole. The production of these fields usually is consumed in the context of group festivities either religious of just for social purposes	
Management /Participation ***The right to regulate internal use patterns and transform the resource system/facility by making improvements***	Concerning the individual land units, the older women in the household will be responsible for everything that concerns the collective production of women at the household level, such as breeding, soil management and also they regulate internal use patterns of use. However, although this was the customary practice, there are cases where the individual "owner" might be entitled to this right Collective production units> usually there is some form of leadership within these groups, particularly in the ones at the *fogão* or *morança* level. In the case of *morança* collective fields, the first wife of	*Same as on the right*

[85] a village (tabanca) that is formed by one or several *morança*: smaller areas usually defined by extended family; the *fogão*: approximately a nuclear family[85], own individual fields for their own specific consumption

	the *morança* head has the responsibility for the organisation the work, control of production for consumption and seed reserves. In the case of the *fogão* similar rule applies. The youth groups Mudjuandades have a more horizontal decision-making process regarding management.	
Exclusion ***The right to determine who will have access, contribution, and, removal rights and how those rights may be transferred***	Lowland farmers either individually or collectively forms have the right to access to the seed, to the harvest of seeds as artifacts, to regulate the internal use patterns of land in the lowland agro-ecological system as well as making improvements to the resource or facility	The majority of female farmers under the customary tenure systems have the *de facto* right on who will have access and management rights over the land producing genetic material of seeds. They also have the right to define: who contributes to genetic diversity on their land and who has the right to the genetic harvest on their land. Nonetheless, customary practice is that the "idea" content of a rice seed belongs to the farmers' community as a whole, where social norms restrain individual property rights over the genetic content of their seeds.
Alienation ***The right to sell or lease extraction, management /participation , and exclusion rights***	Each *fogão* is subject to the authority of the *fogão* male head, which allocates land of each type: to his wives and daughters, each of whom might have their fields and degree of control over at least a part of what is produced. Above the *fogão* head stands the wider land allocation system and social organisation of the tabanca. The land is allocated downwards, through the *morança* or directly to each *fogão* head, by the village elder (homem grande) from the founding family or clan. Therefore, alienation is a right	Despite Seeds' as an idea being internationally recognized in a *de jure* manner as belonging to the state, Guinean Bissau lowland farmers as a community possess the collective customary right to the alienation of agro-biodiversity encapsulated in seed.

	stands with community leaders within each tabanca. *Ex situ*> The same as above	

Customary practices have been shaping the property rights regime over seeds in Guinea Bissau across centuries. The alienation of rural communities by the colonial power before independence and by the state post-independence, with a persistent, resulted in well-established *rules in use* in farmers' community that translate in well-established and relatively resilient property right regimes. In one hand seed as an artifact is embedded in a predominantly private property rights regime, were farmers own a considerable bundle of rights, namely individual rights of access, withdrawal, management and exclusion. While seed as an idea, is ruled by a common property regime where rice farmers' community in Guinea Bissau and across its borders (namely in Senegal and Guinea Conakry) can access, contribute and extract genetic resources among their diversity pool in line with customary rules. Seed as an agricultural input (artifact) is subject to different rules as seed as a genetic resource (idea). Nonetheless, seed governance "*in use*" in the context of the lowland agro-ecological system concentrates more on regulating behaviour and norms rather ascertaining specific bundles of property rights to individuals or groups (See Section 5.2b for detail in *rules in use*). Finally, it is worth pointing out that women working in the lowland production system are not owners of the land, although they enjoy proprietors' rights since they hold the majority of rights except the exclusion.[86]

[86] See Shagler & Ostrom, 2005 for more details on property-rights regimes that classify users according to bundles of rights ranging from authorized user, to claimant, to proprietor, and to owner

6. Multi-level Action Situation Interaction Analysis: Seed Governance, Socio-Ecological Systems and Farmer's Rights in Guinea Bissau

In this section, I will focus on the analysis of interactions and how these interactions can affect outcomes. Here the assessment and analysis of the different core sub-systems of the socio-ecological system (e.g. Governance System (GS), Actors (A)[87], Resource Units) conducted so far, are brought together to inform how **interactions (I)** are affecting or can potentially affect **outcomes (O)**.

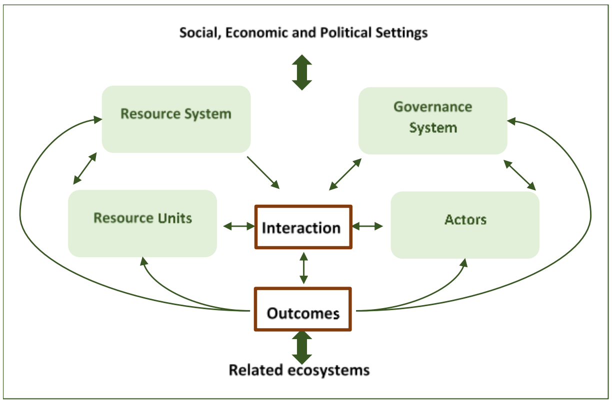

Figure 9. Actions Situation: Interactions (I) and Outcomes (O)

The variables Regime type (GS4), Network structure (GS9), and Historical continuity (GS10) second tier variables characterising the governance system (GS) will be covered in this section since they are informative and supportive in analysing the multi-level interactions and its effects on the outcome of farmers' rights. The Governance Structure schemes presented in the following sub-sections (6.1., 6.2., and 6.4), follows graphic representation of adaptive governance systems in the line of Andersson and Ostrom (2008) and Folke et al. (2005), for example. The implementation of this approach admits graphical explanations based on qualitative data to provide a picture of the actors, links existence and strength to provide insights of the dynamics of different governance structures that interplay with farmers' rights and the socio-ecological system.

Given the complexity and overlapping treaties, agreements and actors underlying the governance of seeds with implications to Guinea Bissau, this analysis will be carried out by disaggregating in three governance sub-systems that that can either affect, either positively or negatively farmers´ rights. I

[87] Detailed information of the actors represented in the figures of the governance structure presented in the following sections can be found as follows: (i) detailed description on the Governance Organisations at the Meta-Constitutional, Constitutional and Collective level (Governance in form) please refer to **Appendix I**. Meta-constitutional, constitutional and Collective Actors and Rule Making Organisations- which some of them represent at the same time **rule making organisations under the governance system and are as well actors of the actions situation**; (ii) On collective and operational level organisations (Governance in use) please refer to 5.2 on Actors.

classify these governance sub-systems as 1) Biodiversity and Farmers' Rights; 2) Plant Variety Protection; and, 3) Regional Harmonization.

This section will examine:

(i) the **status of the implementation of these agendas** at the collective and operational levels,

The Interactions between different components of the socio-ecological system:

(ii) Governance System <> Governance System Interaction. Interactions between different governance systems: (i) International Treaty on Plant Genetic Resources for Food and Agriculture and Convention on Biological Diversity, (ii) International Union for the Protection of New Varieties of Plants, (iii) Regional Harmonization, (iv) Governance system *in use*. (Section 6.1, 6.2, 6.3, 6.4)

(iii) Governance Systems <> Actors. Interaction in the context of laws and regulations affecting specific property rights held by an individual or collective actors and local knowledge over resource units: e.g. seeds. (Section 6.1, 6.2, 6.3, 6.4)

(iv) Governance System <> Resource System Interaction. Interactions related to the fit between scales of the resource (e.g. lowland agro-ecological system) and governance systems. (6.4)

Concerning **Outcomes it will:**

(v) Examine how these interactions impact **farmers' rights**, which can be thought as an equity measure and a measure of social performance. It is assumed that farmers' rights are a necessary condition for the conservation of agro-biodiversity *in situ*.

Finally, this section will also explore interactions between these agendas, and conduct a comparative analysis of the potential ability of each of these agendas to "push down" from meta-constitutional to operational level the *rules in form.*

6.1. Biodiversity and Farmer's Rights Governance Sub-system in a context of State Fragility

This section will explore whether Guinea Bissau farmers' rights are being protected or the potential for protection by the implementation of international regimes concerning farmers' rights and biodiversity: the Convention of Biological Diversity (CBD) and International Treaty Plant genetic resources for food and agriculture (ITPGRFA).

Status of the Implementation

Following the analysis of the literature and interviews with key informants in the areas of agriculture and seed security in Guinea Bissau, it is possible to conclude that the **Access and Benefit Sharing implementation** in Guinea Bissau is virtually inexistent. The ITPGRFA was ratified by Guinea Bissau in May 2006 while the Nagoya Protocol was ratified in September 2013. However there is an uneven representation of the two instruments, aimed at promoting ABS, at the national level. [88]

While in the context of CBD the RGB has appointed the IBAP Director as the focal point of this Convention and other technicians at this institution were to be appointed to positions as Focal Points such as Nagoya Protocol on Access and Benefit-sharing. These appointments reflect the implementation of these instruments at collective choice level. Under the CBD, Guinea´s Bissau's planning efforts are reflected by the Strategy and National Action Plan for the Biodiversity (2015-2020). In strategy's Goal 13 it is stated: "By the year 2020, to maintain, through elaboration and execution of appropriate strategies, the conservation of cultivated species, of domestic animals, sylvan species and of other species of socioeconomic and/or cultural value". Refering to this goal, also a reference is made to the need of "an expansion and a preservation program of local varieties at the INPA level and with some NGOs, and "constituting local collections and banks of genes and seeds and create conservation, exchange, and quick alert networks of animal races and vegetable species in risk". To the achievement of these objectives two issues are considered critical: (i) local involvement of community and the respective safeguards and valorisation of their knowledge and traditional knowledge and (ii) legislative aspect and the regulation with a view to protect cultivated plants and domestic animals. Furthermore, goal 16 states "By the end of 2016, to assure the formation, adoption and function of a simple and efficient juridical-legal aspect which allows the execution of Nagoya

[88] Guinea Bissau Page of the International Treaty on Plant Genetic Resources for Food and Agriculture http://www.fao.org/plant-treaty/countries/membership/country-details/en/c/359291/?iso3=GNB

Protocol". This goal is to be implemented by building up the necessary conditions for the preparation and implementation of juridical, institutional and regulatory instruments relative to ABS in the context of the Nagoya Protocol, as well as provide capacity building of information and awareness. The strategy also makes a reference to a proposal of a Decree for the Organisation of the Valorisation of the Biological Diversity, **Traditional Knowledge** and of Handmade and Artistic Work of Guinea-Bissau that is referred to as accepted (RGB, 2014). However, the wording is vague on what is the formal meaning of to be accepted.

The CBD and the Nagoya Protocol stipulate that ABS conditions must be established between countries providing and countries using genetic resources, through bilateral negotiations[89] however Guinea Bissau has not yet any specific ABS laws or regulations in place. Moreover, even if the timeline for the strategy extends until 2020, there is no sign of legislative activity towards the implementation of ABS related regulations. Irrespective of the complexity of the implementation of ABS referred elsewhere (Pistorius, 2016; Rosendal, 2010; Brink, 2013; Halewood et al., 2016) it is very unlikely that under the current political situation any legislation will be developed with this regards.

For the ITPGRF the picture is even bleaker. There is no focal point in any governmental department, neither have any Benefit-sharing Fund (BSF) project been awarded to Guinea Bissau. Furthermore, concerning the Multilateral System,[90] there is no register of any PGRFA from Guinea Bissau being requested from Africa Rice Gene bank (CGIAR centres). The *ex situ* conservation of Guinean Bissau rice varieties is incipient when compared to other countries in the Region. The Africa Rice Centre genebank holds 62 accessions with origin in Guinea Bissau[91], while for example, it holds 783 accessions with origin in Senegal, 390 in the Gambia and 678 Guinee Conakry. At the national level, the NGO KAFO (see Appendix I for details) keeps a gene bank with seeds from several crops, including rice.

Notwithstanding the importance of local gene-banks at the national and village level as critical sources for *ex situ* conservation, international gene banks are also key important facilities for *ex situ* conservation, particularly in contexts of regional and national level shocks (e.g. natural disasters, war) that can destroy these local *ex situ* conservation facilities. Despite its rich tradition of rice production and agrobiodiversity, the conservation of Guinea Bissauan rice diversity is not well safeguarded by the

[89] Prior informed consent and Mutually agreed terms For more detail on procedures regarding ABS https://www.cbd.int/doc/publications/cbd-bonn-gdls-en.pdf

[90] On ratifying the Treaty, countries agree to make their genetic diversity and related information about the crops stored in their gene banks available to all through the Multilateral System (MLS). This gives scientific institutions and private sector plant breeders the opportunity to work with, and potentially to improve, the materials stored in gene banks or even crops growing in fields.

[91] AfricaRice Genebank Information System (ARGIS)

current arrangements. Safeguarded in a sense that there *ex situ* conservation possibilities are not covered but also in the sense that is it possible under the current absence of regulation regarding ABS to make farmers' genetic resources more vulnerable to biopiracy activities. Overall, the analysis shows that institutions are weak and the *rules in form* to provision ABS and Traditional Knowledge rights, are typically absent or weakly enforced in Guinea Bissau, which is typical with the fragility of the state itself.

The right to save, use, exchange, and sell farm-saved seed and other propagating material is also not recognised in the national law. The National Seed Policy could be a starting point for the provision of these rights at the national level. However, despite the dominance of informal seed systems, particularly in the context of lowland agro-ecology system, the provisional National Seed Policy (2015) (still a provisional document not legally binding) essentially focuses on the formal system with virtually no recognition of *de facto* farmers rights. Notwithstanding, there is some legal space to promote formal recognition of local varieties and informal seed systems. For instance, the policy principles state that one of the objectives is to "Ensure the marketing of new varieties and local varieties that are efficient and adapted to the different agro-ecological and sociocultural environments of the country". The policy also refers to the fact that several studies developed in the framework of international programs such as those conducted by FAO and other development agencies had their primary focus on the organisation of the formal seed system. However, the National Seed Policy recognizes the informal seed system as the main source of seed for Guinea Bissauan farmers and, despite that, little is known about this critical sector. On the lack of knowledge of the informal seed system, it concludes by saying more is needed to know about the informal sector and that "law on seeds and regulatory mechanisms must take into account the informal sector and its main actors to avoid a gap between policy and current practice" (MDRA, 2015, p.7). The policy also has an Article on Seed security, among other policy measures it states the following points:

(i) The Government will promote the role of farmers' communities in seed security: To this end, it is planned to promote the establishment of seed banks at the community level to ensure their availability in the event of a bad season or natural disaster;

(ii) The government will ensure through the research institutions to preserve the "traditional" plant material selected *in situ* by the populations and therefore to guarantee the preservation and the enrichment of the biological diversity of the adapted seeds.

Although recognising the importance of the informal sector as well as the need to promote diversity and protect established practices, the Policy does not have an explicit stance on ensuring farmers' seed sovereignty. The protection of farmers' rights and seed sovereignty could be made more explicit in the light of ITPGRFA and CBD commitments. The policy should provide guidance on how to protect and reconcile farmers' rights in line with the strong statements such as the ones found in the international legal commitments, such as OAPI's Bangui Revised Agreement (See below section Plant Variety Protection and Farmer's in a context of State Fragility). Overall, the processes and legal instruments to which these formal legal rules can represent the "rules-in-use" (or "working rules") at a collective choice level are yet to be developed and implemented.

Seed Governance Structure in the Biodiversity and Farmers' Rights Agenda (GS9)

The **Governance Structure** provides insight on the links strength between different organisations and how these can affect the enforcement of farmers' rights and the protection of local agro-diversity, at an operational level (***Figure 11 Seed Governance Structure in the Biodiversity and Farmers' Rights Agenda***).

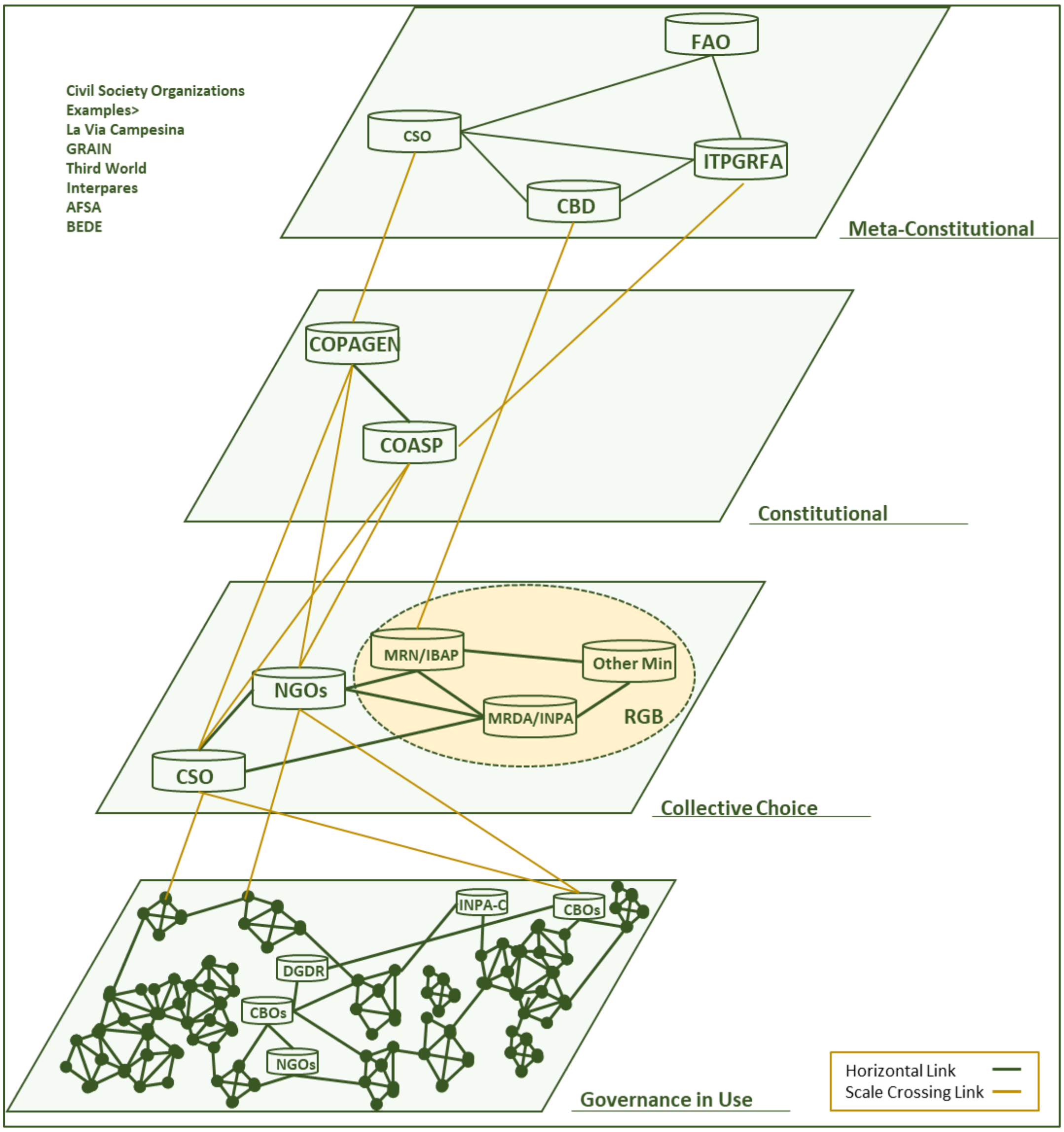

Figure 10. Seed Governance Structure in the Biodiversity and Farmers' Rights Agenda

The weakness and the nature of the links within and across levels in the **Biodioversity and farmers' rights governance structure** together with state fragility, make its implementation at an operational level virtually impossible. The CBD has three major objectives: conservation of biodiversity, sustainable use of its components and equitable sharing of benefits from the use of genetic resources. However, most of resources that flow into Guinea Bissau are focusing on biodiversity conservation, particularly in the areas of forest conservation operating at the collective and operational levels (RGB, 2014). Efforts towards ABS component of CDB are nothing more than the appointment of the focal point and the development of a strategic biodiversity plan (mentioned in the section above) with some ABS and Traditional Knowledge related rights considerations. The absence of a National Focal point for the ITPGRFA[92] makes the link between the meta-constitutional and collective choice level very difficult. Such a link would allow the flow of capacity building and financial resources (e.g. Benefit Sharing Fund). The absence of such a flow makes the diffusion of the ABS and farmers rights agenda impossible at the constitutional level. Opportunities to integrate provisions particularly concerning farmers' rights to the domestic level, namely seed policy, laws and regulations, are yet developed and seriously limited under this context. For the same reasons farmers' rights to participate on relevant decision-making is also not being granted by the government while civil society at the collective level despite being engaged, its limited in number and resources to effectively engage farmers at the operational level[93]. Within the non-governmental sector, there is a dynamic and strong advocacy network around farmers' rights in the context of the ABS agenda namely international non-governmental organisations. Examples of organisations at the Meta-constitutional level, working over these issues are the Third World Network, Grain, Alliance for Food Sovereignty in Africa (AFSA) and Biodiversity, Exchange and dissemination of Experiences (BEDE). While at the constitutional level, regional organisations such as Coalition for the Protection of African Genetic Heritage (COPAGEN) and West African Peasant Seed Committee (COASP) also focus on improving not only the legal content of these international laws but also its operationalisation, with the key objective of ensuring that farmers' *de facto* rights are ultimately represented by *de jure* laws.

At the level of collective choice, outside the government spheres, there is limited awareness about these international treaties and how these can influence farmers' *de facto* rights[94]. The NGO Tiniguena represents COPAGEN in Guinea Bissau, jointly with the Peasant Federation KAFO and the Consumer Protection Association (ACOBES). COPAGEN-Guinea-Bissau branch has 21 members and have defined issues around land grabbing and the safeguarding of traditional seeds as COPAGEN-GB's priority and unifying themes. Civil Society Network for Sovereignty and Food and Nutrition Security in Guinea-Bissau (RESSAN-GB) represents 52 civil society organisations working in food sovereignty themes. Guiarroz and Proagri are the two organisations working in the governance *in use* system which are

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[92] http://www.fao.org/plant-treaty/countries/membership/country-details/jp/c/359291/?iso3=GNB
[93] Interview 7 and 8
[94] Interview 7, 8, 9 and 10

represented in this network. Despite the limited awareness on the treaties in their own right, two projects promoted by two local NGOs aimed at promoting farmers' rights issues. The project "Promotion of Food Sovereignty and Traditional Medicine with Gender Equity in the Regions of Oio, Cacheu and Bafatá (Guinea Bissau)" promoted by KAFO and SODEPAZ (2012), which among other things aimed at promoting techniques, preservation of seeds and diffusion of traditional seeds. Also, the "Kil ki di nos ten balur" project – loosely translated as "what we have is priceless" promoted by Tiniguena, included activities focused on supporting seed savers to recover local varieties, and to multiply and distribute the best seeds. Of these two projects, only the former had some, though limited, intervention in Bafatá region.

At the operational level lowland female rice farmers' community have virtually no awareness of their rights and the possible opportunities arising from farmers rights provisions within these international legal mechanisms[95]. Among the recommendations arising from the Global Consultation on Farmers' Rights held in Indonesia in 2016, was the need to "encourage contracting Parties and donor agencies to enhance and financially support capacity-building of farmers (especially of small-scale farmers) by farmer groups and civil society organisations in respect of their rights, developments that may challenge the realisation of Farmers' Rights, and the importance of active farmers' engagement in relevant national, regional and international processes"(FAO, 2017, p. 52). The only West Africa farmers' organisation that participated in the event was COASP Benin. Overall this reflects that farmers' participation in not only an issue in Guinea Bissau. (see Appendix I for more details on these organisations and relations among them).

Interactions (I), Farmers' Rights (O) and State Fragility

On the whole, there is evidence that the current system in place is considered to be too theoretical, too bureaucratic and legalistic (e.g. Pistorius, 2016; Rosendal, 2010; Brink, 2013). Such constraints are even more difficult to overcome in the context of state fragility and pose even more stringent challenges for effective implementation. Countries in a situation of political stability have encountered multiple challenges concerning the domestic implementation of ABS. Problems such as the complex interface between these two systems (Christinck & Tvedt, 2015; Rosendal, 2010; Brink, 2013); Lack of coordination, fragmented and conflicting responsibilities and division of labour (Rosendal, 2010; Brink, 2013; Pistorius, 2016). Guinea Bissau has minimal legislative and institutional capacity, weak

[95] Interviews 7, 8, 9 and 10

coordination, and constrained financial resources. This context makes the conformity of national laws, regulations and procedures with their obligations under both CBD and ITPRG very unlikely in the short and medium term. The Model law that if adopted by Guinea Bissau could provide a good *sui generis* regime to protect farmers' rights, however, it was rejected by all members of OAPI, since not adopting the Model Law was a requirement to adhere to the Bangui Agreement, under the UPOV model of 1991. Hence, family farmers in the lowland agro-ecology, have benefited little from the rule *in form* provided by the 'formal' governance system characterised by the **Figure 8***.*

6.2. Plant Variety Protection Governance Sub-system and Farmer's in a context of State Fragility

This section will examine Guinea Bissau farmers' rights in a context of increasing pressures being exerted on African governments to adopt Plant Variety Protection (PVP) related legislation.

Status of the Implementation

At present, Guinea Bissau is bounded to the UPOV under OAPI Bangui agreement as well as through the EU-West Africa Economic Partnership Agreement (See section 4.2b for details). Bangui revised agreement translates into Bissau Guinean farmers rights as follows. For seeds that are protected under PVP: farmers can collect and replant seeds, but only for trees and ornament plants; it is not possible to harvest the seeds, exchange, offer or sell them. If an inspection finds probable causes of infraction, seeds can be seized, the cultivated crops can be destroyed, and the crop and the product from the harvested plant can be seized. Concerning the scope for privatization (PVP or patent), all species - including wild can be privatized, privatized varieties can then be used to obtain new varieties. Also local seeds can be privatized if "discovered" and privatization extends to similar pre-existing varieties. Moreover, these type of offense may lead to a fine and imprisonment (OAPI, 1999). Hence, Breeder's rights are well protected in Guinea Bissau since these are provisioned under the Bangui agreement.

Seed Governance Structure in the PVP Agenda (GS9)

This **governance structure** diagram (**Figure 12 Seed Governance Structure in the PVP Agenda**) illustrates the larger number of organisations pushing the PVP agenda at both Meta-constitutional (EU, UPOV, WIPO, WTO) and Constitutional Level (ECOWAS UEMOA, OAPI), with both strong horizontal and cross scales links.

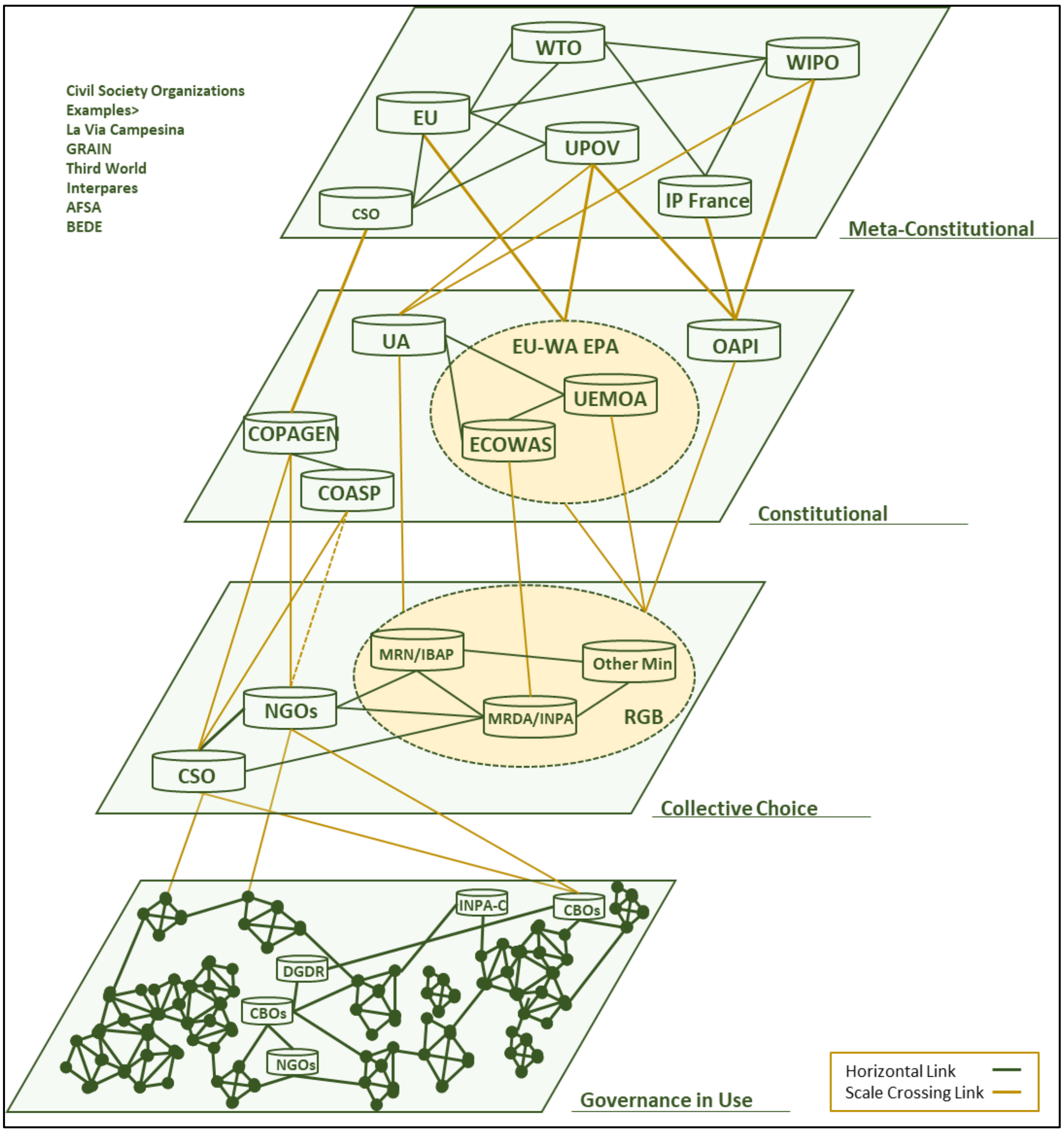

Figure 11. Seed Governance Structure in the PVP Agenda

Although not represented in **Figure 12**, many of these organisations at the meta and constitutional level, have extensive support by private seed companies which are likely to benefit from these agendas (GRAIN, 2005; ACBIO, 2012; Hubbard, 2009; Haugen, 2015). Examples of companies extending their presence in Africa are Monsanto with five subsidiaries[96] operating in Africa and Technisem (France)[97] with four companies, three of which in West Africa (Kuyek, 2002). In the case of the Regional Harmonization Agenda, associations of private sector seed enterprises are formally engaged in the process, particularly at the constitutional level, while within this agenda these interactions do not seem so explicit. Organisations advocating on farmers rights, such as international advocacy groups, are also numerous (e.g. AFSA, GRAIN, BEDES, Third World) with also strong horizontal links among them and to constitutional level civil society (e.g. COPAGEN and COASP) (AFSA, 2009; Declaration, 2014). However, unlike the ITPGRFA the processes of developing PVP related laws at the meta-constitutional and constitutional level are opaque, and participation and involvement of civil society is limited (Strba, 2017; ACBIO, 2012; Haugen, 2015). So despite loud criticism over these processes (e.g. UPOV, OAPI, EU EPA-WA) by these advocacy organisations and civil society, there are limited channels for participation and pressure for changes in the rules being established by these different instruments at the meta-constitutional level. On the other hand institutional links between these civil society organisations with the collective choice level are solely with civil society organisations (e.g. NGO Tiniguena; ACOBES, KAFO in the context COPAGEN), while with Bissau Guinean government the links are inexistent. Also, horizontal links between NGOs, CSO and Government to discuss issues pertaining PVP are virtually inexistent[98]. Civil society in Guinea Bissau, is more likely to be engaged in the context of donor-funded development projects through participatory workshops supported by these institutions, than the government[99] to promote national debate over issues such as ratification of PVP related regional agreements (EPA UE WA, OAPI Bangui Agreement). Finally, the limited resources and geographical scope of collective choice level NGOs and CSOs, limits the number of linkages and its strength to farmers at an operational level. Virtually none of the lowland farmers is aware of these international commitments nor of the potential damage that these can pose to their seed (and food) security and sovereignty[100] (see Appendix I for more details on these organisations and relations among them).

[96] Cargill (USA) Carnia (South Africa) Delta and Pine Land (USA) Monsanto (Kenya) National Seed Company of Malawi Sensako (South Africa)
[97] Tropicasem (Benin, Mali, Cameroon, Senegal) Agritropic (Nigeria) Semivoire (Côte d'Ivoire) Nankosem (Burkina Faso)
[98] Interviews 7, 8, 9 and 10
[99] Interview 8
[100] Interviews 7, 8, 9 and 10

Interactions (I), Farmers' Rights (O) and State Fragility

The fact that rules established under this governance agenda are affecting the *rules in use*, this does not mean that there are **no potential risks, challenges nor opportunities** for lowland female farmers rights.

Like many OAPI members, Guinea Bissau has not implemented PVP at the national level, meaning that the development of new varieties at the national level cannot be patented (See De Jonge, 2014; De Jonge et al., 2016). The lack of PVP legislation could undermine breeders and producers incentives (See discussion in 5.1 TRIPS, UPOV and OAPI Agreements). Incentive issues could occur, if Guinea Bissau had more mature formal seed sector with an innovation system in place, either private or public, however, has shown in detail in section 5.2 this is not the case. Furthermore, even if Guinea Bissau had the legislation in place, the administrative requirements would be too onerous. The fact that virtually all seed used in the rice lowland agro-ecology is farm-saved, making plant breeders' rights at the national level rather irrelevant to the Bissau Guinean economy. Not to say that it is innocuous to Bissau Guinean farmers since if one OAPI member country grants PVP on a variety, it can be automatically released in all the countries. Bangui agreement allows the provisions for the protection of farmer's rights within the national law. However in the absence of such law (see Section 4.1 above for details on ABS and Farmers Rights in place Guinea Bissau) Guinea Bissau does not make use, of the narrow but existent, leeway to protect farmers rights through the establishment of a *sui generis* regime. Even in the event of having a *sui generis* system in place, the ability individual farmers or communities to comply with the formalities for acquiring rights such as registration may be unfeasible due to the complexity and possible cost of the procedures to farmers (Halewood, 2016; Pistorius, 2016). Additionally, enforcing any conferred rights would require considerable effort and resources (Halewood, 2016; Timmermann & Robaey, 2016; Pistorius, 2016).

The survival of commons regimes is highly dependent on sanctioning possibilities (Ostrom 1990), and this has implications for lowland rice farmers in a context of state fragility. Enforcing *sui generis* regimes is extremely challenging for the majority of developing countries (Srinivasan, 2003, Halewood, 2016) it is even more so in a context of poverty and limited statehood. The majority of farmers' communities in Guinea Bissau are affected by high levels of poverty making it very difficult for farmers or communities having the resources and the agency to identify infringements and defend the provisioned rights. Firstly, it might be very difficult for the rights holder to monitor whether an infringement has occurred (Salazar, Louwaars & Visser, 2007). Secondly, if an infringement has been identified by a farmer or a community, setting up a legal action in court would be costly and beyond the reach of farmers/communities (Halewood, 2016). Thirdly, litigation assumes a state were the rule of law is established. However this is not the case in Guinea Bissau. Problems of security and justice sector reforms are at the core of the country's fragility (AfDB, 2016). There is a significant shortage of courts, police stations and appropriately trained state employees, especially in rural areas where the possible issues around PVP related rights may emerge. State Fragility it is very likely to seriously hinder the prospects of establishing and enforcing a *sui generis* system to protect and reinforce farmers' rights, and their underlying seed sovereignty.

State fragility poses additional challenges since it makes Guinea Bissau more vulnerable to international pressure to pass PVP legislation at the national level. ACBIO (2012) has reported that the World Intellectual Property Organisation (WIPO), the UPOV Office and the French IP office pressured West African countries into adopting and ratifying UPOV 1991 via the Revised Bangui Agreement in 1999. UPOV, WIPO and the French IP office fully participated in the development of the text leaving little or no opportunity for formal interstate negotiation. Accordingly, Deere (2011) explains the negotiation process on the introduction of Annex 10 in the Bangui agreement was determined by: "(i) dependencies on global intellectual property organisations, (ii) closed processes, (iii) limited state capacities, (iv) strong external influences by developed states and (v) lofty promises on overall benefits in the realms of aid, trade and investments" (pp. 241–242). If OAPI members, with much stronger states and bargaining power, adopted UPOV to the regional sphere through the Bangui revised agreement, the greater vulnerability has Guinea Bissau to similar pressures into developing domestic laws, given that is a fragile country with a rent-seeking political-military elite.

The farmers' relative isolation from the formal seed system may have granted Guinea Bissau a relatively untouched rich rice related agro-biodiversity (See 3.2 for details on resource units agro-biodiversity), however as in other biodiverse-rich sectors in the country, it is not without risk. Several African civil society organisations have concerns over biopiracy[101] (De Jonge, 2014) and these are increased in a context of greater agro-biodiversity (Argumedo & Pimbert, 2006). Even if most farmer-bred varieties are unlikely to gain a significant market share in the commercial sector, biopiracy is a problem when a variety turns out to have the potential to achieve such a share. There are already several cases where biopiracy over PGR has been reported (De Jonge, 2014; See GRAIN & La Via Campesina, 2015 for more examples). For example, the 'violet de Galmi' onion a hugely popular variety from Niger, was subject to biopiracy by a private breeding company. In 1990's a private seed

[101] Biopiracy, or the stealing of genetic material and knowledge from communities in the gene-rich developing countries

company in Senegal, Tropicasem, a subsidiary of the French seed company Technisem, further bred the onion with the aim of marketing it exclusively. The company applied for a Plant Variety Certificate at the OAPI, claiming the popular onion as its own obtaining exclusive ownership rights in all OAPI member states. However, farmers in Niger found out that a private company had claimed exclusive rights to their onion asked the government to act on their behalf in this case of biopiracy. After the conflict that ensued, OAPI revoked the property rights on the onion under the name 'Violet de Galmi', an example of a victory[102] for the onion farmers against biopiracy (GRAIN & La Via Campesina, 2015). Illegal behaviour relating biodiversity in the forest sector has been extensively reported in Guinea Bissau, notably timber illegal logging of rare tropical species (rosewood) has been carried out by Chinese companies with limited state control and with the alleged active participation of state's officials. These activities were particularly prevalent in situations of increased political instability such as the 2012 coup.[103] Therefore agro-biodiversity, state fragility and a rent-seeking elite, might provide all the right ingredients to make Guinea Bissau the perfect target to illegal bioprospecting leading to biopiracy.

Despite poverty and state fragility, there are other mechanisms that farmers can resort to protect their rights. Guinea Bissau farmers might not have the government to resort for support, but they have strong civil society organisations at the operational and collective level that can engage in supporting farmers against situations undermining their *rules in use*. For example, in Ghana students and trade unions joined farmers to oppose a restrictive seed law (GRAIN & La Via Campesina, 2015). In Guinea Bissau, rural civil society is marked by a historical landmark of resistance against successive forms of power, which are likely to emerge if confronted with attempts to undermine long enduring rights to seeds (See section 3a). On top of a strong rural society, there is also civil society at the constitutional level promoting and advocating farmers' rights.

In sum, organisations pushing the PVP agenda are formal, well organized, with strong and formal links, when compared to the farmer's rights agenda. This contributes to an uneven balance of forces that translates in the potential loss of *de facto* rights of Guinean lowland rice farmers'. The ratification of

[102] Other examples of victories: 1997- case against a Texas-based company (RiceTec) acquired US Patent on basmati rice lines and grains; 1999-two Australian government agricultural agencies attempted to patent chickpeas grown by subsistence farmers in India and Iran. However patent application was a protest by some activists Mgbeoji, (2014)

[103] https://uk.reuters.com/article/uk-bissau-logging-insight-idUKKBN0E10C820140521;
The Guardian. 2014. China's Red Furniture Craze Fuelling Illegal Logging in Guinea-Bissau. https://www.theguardian.com/globaldevelopment/2014/jul/23/china-furniture-rosewood-illegallogging-guinea-bissau

UPOV 1991 via the Revised Bangui Agreement seriously limits the Guinea Bissau's scope to formally protect its farmers' rights. Despite being limited, opportunities for farmers in Guinea to protect their *de facto* rights although limited do exist. Guinea Bissau has a resilient and dynamic rural civil society (Forrest, 2003; See section 3 State Fragility, Rural Society and Seed Systems for more details on the importance of civil society), if well informed, with their capacities strengthened and linked with regional and international organisations, they can effectively push towards a seed law and regulations, more balanced towards farmers' rights. Despite of many authors suggesting that *sui generis* regimes, if well adapted to local context, are instrumental in reinforcing farmers' rights in the context of more favourable legal environments towards breeders' rights (Haugen, 2015; Halewood, 2016; De Jonge, 2014; Correa, Shashikant & Meienberg, 2015; De Jonge & Munyi, 2016), such a system is unfeasible in Guinea Bissau for the reasons stated above. Hence, in the same line of the farmers' victories presented above, the most powerful tool to protect their rights is through protecting, exercising and enhancing lowland farmers' agency. On the whole, irrespective of the rule in form stemming from rulemaking formal organisations, the *de facto* governance and *rules in use* in Guinea Bissau provides farmers communities with Plant Variety Protection customary rights.

6.3. Regional Harmonization Governance Sub-system and Farmer's Rights in a context of State Fragility

This section will examine Guinea Bissau farmers' rights in the context of fast-tracked regional harmonisation process that is being currently promoted across West-African countries.

Status of the Implementation

The transposition of ECOWAS regulations to domestic law and its implementation are virtually non-existent. According to CORAF/WECARD (2014) report on the harmonization status by the participant countries, Benin, Nigeria and Togo were performing well, were the harmonisation report classifies these countries has having addressed or being in the process of addressing 12 out of the 13 elements in the measures[104]. Conversely, the level of implementation in Cape Verde, Guinea Bissau, Liberia and Chad are classified as poor since they have not applied any of the measures within the key activities. Nonetheless in 2015 WASP[105] held a national training workshop on "quality control and seed certification." This training was targeted at managing postitions of the Control and Certification Service and inspectors, seed controllers and national seed laboratory analysts, with a total of 25 participants including seven women. The slow pace of Guinea Bissau in proceeding with the harmonisation process is a reflex of the political instability which results in the lack of governments' ability to dedicate resources to move forward in implementing these measures.

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[104] Publication in official Journal; Review of seed regulatory framework: (i) National seed law, (ii) Decree instituting national catalogue of species and plant varieties, (iii) Decree creating the National Seed Committee, (iii) Decree on seed technical regulation relating to production, quality control and certification sector; Adaptation of Procedure Manuals: (i) Variety release and registration, Quality control and certification, Phyto-sanitary certification; Capacity Strengthening: (i) Human resources, (ii) Material resources, (ii) Financial resources.

[105] http://www.coraf.org/wasp2013/?p=520

Seed Governance Structure in the Regional Harmonization agenda

The **Governance Structure in the context of Regional Harmonization agenda** shows that, unlike PVP agenda, the actors pushing this regional harmonisation processes have stronger links across all different scales. While Civil Society is organised in the same manner as the above agenda, from the meta-constitutional to the operational level, since many of these issues overlap. However, the links between the regional institutions promoting the seed harmonisation process from the constitutional (ECOWAS, UEMOA, CORAF, WASC) to the collective choice level government institutions (MRDA/INPA) is much stronger.

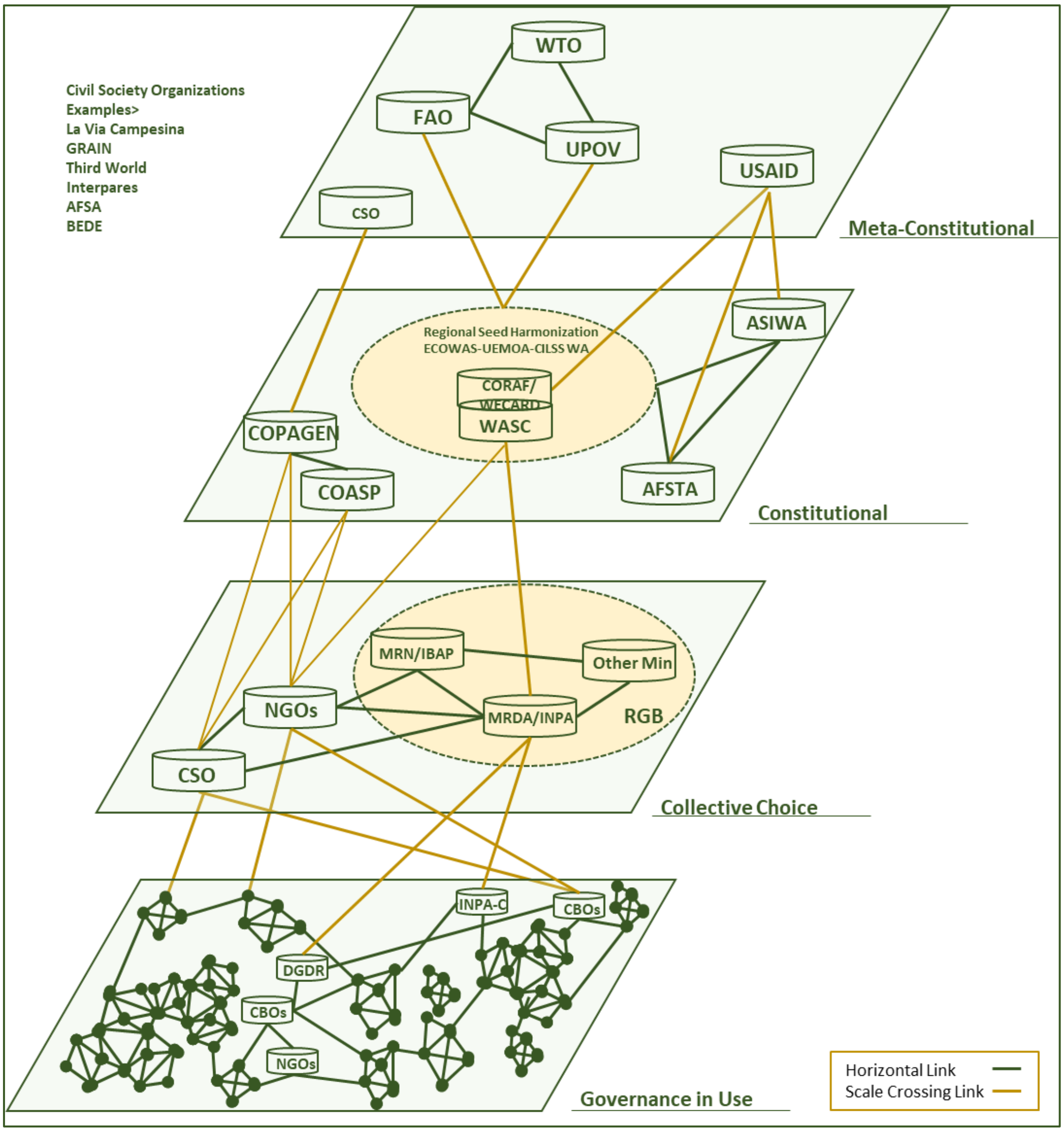

Figure 12. Seed Governance Structure in the Regional Harmonization Agenda

Moreover, FAO has been funding the whole process at the regional level while USAID has been funding particularly the WASP, a specific program being implemented at national level in all regions ECOWAS members as well as the setup and reinforcement of the Alliance for Seed Industry in West Africa. Around most of the ECOWA-UEMOA-CILSS Member States, have private seed sector organisations, some of which are affiliated to regional and continental networks such as NSTA members and AFSTA members or non-member, West Africa Farmer Organisations Platform (ROPPA). Where there is no private sector seed organisation at the collective level, the Regional Seed Committee, supports the establishment of national private sector associations and accompany them on their membership in regional and even continental networks and platforms (e.g. AFSTA, ROPPA, Africa Seed, ASIWA, etc.) (CORAF/WECARD, 2014). Seed industry activity is concentrated mostly in the Guinea-Savannah agro-ecological zone (Mayet, 2015), which includes Guinea Bissau, and it was identified by the World Bank as being of high-economic potential (as cited in Mayet, 2015). The strong link with the private sector is a result of one of the key program components of WASP being the development of a strong West African private sector to ensure the supply of certified seeds of standard quality (USAID/West African Seed Program, 2015).

At the operational level, there are good links in this context between MRDA-INPA with Contuboel INPA, as well between INPA-Contuboel and Farmers Community Based Organisations (e.g. Agromultipliers, APALCOFE) and NGOs (e.g. Guiarroz) working in the agricultural sector (See section 5.2). Farmers' at an operational level are more aware of the Quality control, certification and variety release processes implemented under ECOWAS regional seeds than Intellectual Property over their genetic resources[106]. The increased awareness over these issues was partly a result of the projects promoted by FAO and Africa Rice (See section 3.1 b). Particularly FAO project capacitated INPA Contuboel staff and has trained 360 seed producers (agro-multipliers) in Contuboel covering issues of quality control and certification. Despite being aware of these formal processes, in the same stance as the PVP agenda, it is very unlikely they are aware of risks that these may pose. These links are likely to be further strengthened shortly as a result of "Rice Value Chain Development Project in the Regions of Bafatá and Oio" promoted by the African Development Bank. Among the bank's program activities is the strengthening of access to certified seeds and quality inputs and setting up a revolving fund for the procurement of inputs (fertilisers and seeds). It is worth pointing that the project will seek to procure certified seed outside Guinea Bissau and does not entail activities to support the establishment of such system (AfDB, 2017).

[106] Interviews 8, 9 and 10

Interactions (I), Farmers' Rights (O) and State Fragility

The more effective trickle down of these processes along the different actors from constitutional to the collective and operational arenas, and a stronger presence of the private sector at the constitutional level **does not necessary translate into changes into the *rules in use* of farmers**. The implementation of the system will require some measures to assist the Government towards a simple routine control to seed certification. The first phase of the certification process consists on publishing the variety on the catalogue. This is a critical step since only varieties registered in the National Catalogue of Species and Varieties or on the regional ECOWAS can be produced and certified. The second phase is focused on technological certification process, which concerns analysing the specific purity and the germinative capacity of the seeds, as well as the verification of their health status which requires an Official Seed Control and Certification Service (SOCC) to be in place. However, any of these steps are far from being implemented. Beyond the lack of skilled staff and equipment's to implement the SOCC, seed regulation and the complementary seed law at the national level, are not yet developed and promulgated. As well as the legal texts relating to the creation of the National Council of Seeds and Plants (CNSP), the National Catalogue of Species and Varieties (CNEV), the committee for the approval of varieties, accreditation and approval of seed establishments. Furthemore, at a more operational level, there is the need to control quality on the field and storage. Accordingly, seed multiplication takes place in a plot, under a contract between the farmer-multiplier and organization with the mandate to control these issues at the farm level. This contract defines strict techniques, formalised by the technical regulations annexed to the regulatory texts adopted by the Ministry in charge of Agriculture (FAO-MDRA, 2015). To put all these systems in place, administer and enforce, demands high level financial, technical, administrative and judicial capacity from Guinea Bissau government.

However, this **does not mean that these processes implemented under ECOWAS regional seed harmonisation regulation, do not pose risks to farmers' seed sovereignty** in Guinea Bissau. The regional catalogue developed under this process is comprised by the national catalogues of each member state. Also, the harmonization regulation specifies that to be part of a national list of varieties that can be sold within the region, varieties must be Distinctness, Uniformity and Stability (DUS) with demonstrated value for cultivation and use (VCU) (Rohrbach et al., 2003; FAO, 2008; Halewood, 2016) in a similar stance as UPOV. Under this setting the exchange of seeds between farmers and seed saving becomes illegal, since many landraces and varieties that farmers use may not meet these criteria

(Christinck & Tvedt, 2015; Wattnem, 2016; AFSA & GRAIN, 2015, Halewood, 2016). Regional harmonisation is thought to create larger markets for the seed industry and widening the choice for farmers (Rhonbarch et al., 2003; Halewood, 2016). However, as argued by Wattnem (2016) "behind the façade of the seemingly good intentions of the certification and standardisation requirements of many new seed laws lie a series of negative consequences" (p.14).

The ECOWAS regional seed law harmonisation initiatives have been subject to considerable criticism by civil society organisations (e.g. GRAIN, 2005; ACBIO, 2012; AFSA, 2013) although there is some scope to protect farmers' seed sovereignty rights. Some of these harmonisation rules leave room for the maintenance less stringent standards and alternative registration lists for varieties (Halewood, 2016). For instance, in "India Protection of Plant Varieties and Farmers' Rights Act" provides rights to farmers who breed a new variety Article 39(1)(i): "a farmer who has bred or developed a new variety shall be entitled for registration and other protection in like manner as a breeder of a variety under this Act." While Malaysia's New Plant Varieties Act 2004 (Act 634) replaces standard eligibility requirements for plant variety protection of stability and uniformity are replaced by the requirement of identifiability[107], allowing for a less rigorous examination procedure. However, deviations from UPOV alike DUS requirements is only possible in states that need only to comply with the TRIPS requirements and are not tied to the UPOV requirements (Haugen, 2015; Kanniah, 2005). The fact that Guinea Bissau is OAPI member again makes it more difficult for the use of existing leeway towards farmers' rights in the context of the Regional Harmonization agenda.

One of the claims by many advocacy organisations is that this process of regional harmonisation is a collective effort towards a bigger seed market to benefit the local seed companies in the various regions, including their headquarters in the North (GRAIN, 2005; ACBIO, 2012; AFSA & GRAIN, 2015). However, most of the multinational seed companies subsidiaries are placed in countries with more commercially oriented agricultural market (e.g. Senegal, Mozambique, Zimbabwe, Tanzania; for a detailed list of Multinational Seed Operations in Africa see Kuyek, 2002). The same applies for private small and medium seed enterprises registered in West Africa, which are in greater number in Senegal and Burkina Faso, with no reference to Guinea Bissau's seed private sector (for details see USAID, CORAF & ECOWAS, 2014). The absence of a reference to Guinea Bissau in this context, might be an indication that Guinea Bissau's market is not the most attractive for private seed sector development.

[107] Section 14(2) Malaysian PVP Act. "Identifiable" is defined in Section 14(3)(e) as: " ... (i) it can be distinguished from any other plant grouping by the expression of one characteristic and that characteristic is identifiable within individual plants or within and across a group of plants; and (ii) such characteristics can be identifiable by any person skilled in the relevant art

Possible causes are the persistent state of political instability (see Section 3) in general, and by the limited resources of the lowland farmers, in particular (see Section 5.1 on Users subsection). Hence the small market potential for commercial seeds in Guinea Bissau is likely to lower the private sector "demand" for quality control and certification rules enforcement by the Guinea Bissauan State and consequently a lesser incentive for the state to enforce these regulations.

Looking at experiences of implementing similar certification systems elsewhere can provide useful insights into the case of Guinea Bissau. In Mali, a similar seed regulation was enacted aiming at ensuring farmers' access to high-quality seed as a way to promote agricultural production and enhance food security. A case study looking at this process showed that despite these objectives the majority of farmers continued to rely on their traditional "unregulated" seed systems. The certification institutions were placed in Bamako, with the limited scope of enforcement and the costs of certification were very high for the majority of farmers (Sidibé, Totin, Thompson-Hall, Traoré, Traoré, & Olabisi, 2018). This picture provides insights on the possible outcomes in Guinea Bissau once such a system is in place. There is a great probability of a very limited implementation will occur in Guinea Bissau even in the event of overcoming all the administrative issues raised above.

The findings above should be considered in the context of state fragility, which curtails the ability of this policy agenda to change the *rules in use* at the operational level. Since the state does not have the resources to enforce and sanction non-compliance with quality control and certification rules underlying the ECOWAS system. For the particular context of lowland farmers, the fact that the seed system used being mainly informal with a residual presence in the formal markets makes it less likely of non-conforming local seeds being illegally traded in the market. However, other productions systems that are more embedded in the formal market might be negatively affected by the harmonisation process. Irrespective of Guinea Bissau's constraints posed by the Bangui Agreement signatory in the context of OAPI and the limited ability to implement and enforce certification and quality control system, the Guinea Bissauan government, could offset the potential counterproductive effects on farmers right's by developing regulation in terms of seed certification and control that recognized particular circumstances where the stringent criteria could be relaxed.

6.4. Interactions and Influence of different Governance Systems and Agendas

This section will briefly explore the interactions and relative influence of these different governance agendas while examining on how the governance regime type characterizing these agendas might shape the rules under the governance regime type (GS4) *in use* by Guinea Bissau female farmers. This section also provides insights of the historical continuity (GS10) of these different regimes to distinguish between systems of governance that have been in place for long periods from those that are more recent in form. This section will evaluate these different governance systems and their interactions, in light of the outcomes. The two main governance systems working simultaneously with more or fewer interactions have been labelled as the ***governance in form,*** formed by actors involved in the different international Agendas of Biodiversity and Farmers' Rights, PVP and Regional Harmonization, and ***governance in use,*** involving the actors and the rules at the operational level.

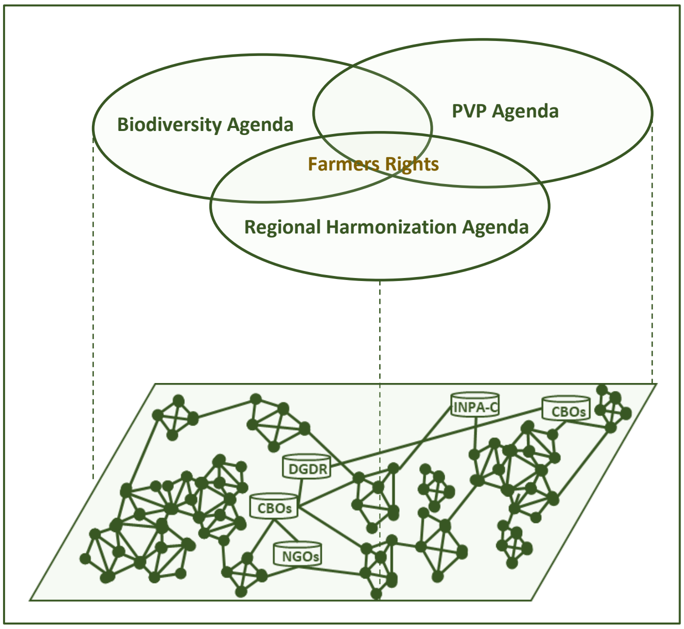

Figure 13. Interactions between Governance Systems

Governance *in form* Versus Governance *in use* (I) and Farmers Rights (O)

The ***governance in form*** is predominantly cross-jurisdictional, and it can be characterized as a Type II[108] governance. The Type II governance is "complex patch, fluid, a patchwork of innumerable, overlapping institutions" (Hooghe & Marks, 2003, p. 4). While the ***governance in use*** regime is more difficult to typify since we have many forms of governance interacting at the same time at a more operational level, such as between governance systems of the formal state and customary governance systems. Given the rather well-defined boundaries between these two systems particularly in the rural areas where the presence of the state is less evident, there seems to be a predominance of the customary governance systems. The customary governance systems fall under a Type I categorisation

[108] Type I: conceives of dispersion of authority to general-purpose, nonintersecting, and durable jurisdictions. Type II: A second type of governance conceives of task-specific, intersecting, and flexible jurisdictions.

characterised “dispersion of authority to a limited number of non-overlapping jurisdictions at a limited number of level”.” (Hooghe & Marks, 2003, p. 4).

Moreover, under the particular context of seed governance a **polycentric**[109] **governance system**, seems to be emerging were many actors at the constitutional (e.g. COASP, COPAGEN), collective (e.g. Tiniguena, KAFO, TESE and LVIA) and operational level (e.g. Farmers, GUIARROZ, APALCOF, CAMPOSSA) are already promoting and finding out ways to enhance seed sovereignty and local agro-biodiversity, **at smaller scale and lower levels**. This governance regime also falls under the type II governance and interacts with rules emerging from the customary governance system, as shown in section 5.2b. In this particular context, the rules emerging from the ***governance system in form*** are expected to affect the rules *in use* at the operational level under the ***governance system in use.*** However, as shown in detail in the previous subsection the situation of fragility in Guinea Bissau curtails every possibility of interactions between these two governance systems for better - balancing more towards farmers' rights, the outcome under investigation, or for worse - balancing more towards breeders' rights.

One of the key attributes that governance regimes have to be more effective in solving a particular problem is the “matching principle” labelled by Ostrom (2010). This principle states that: “By matching jurisdiction with the scope of a given problem, the institutional structure can ensure the greatest "match" between a given problem and the institutional response” (Adler, 2015, p. 133). The matching principle can partially explain the relative performance of the different **governance *in form*** and **governance *in use*** systems. This principle seems to fit into ITPGRFA and CBD performance in particular, where there is a mismatch between global scales jurisdiction of these instruments and the scope of the farmers', rights and biodiversity issues which is local, at an operational level. Beyond the bureaucratic complexities associated with both regimes, the difficulty of making these governance systems *in form* become *in use* systems can also be explained by the failure to comply with the matching principle. With respect to both customary and polycentric systems that comprise the governance system *in use*, they are more likely to be effective as they fulfill to a great extent the matching principle. The polycentric system that has been evolving around the management of lowland

[109] 'Polycentric' connotes many centers of decision making that are formally independent of each other. Whether they actually function independently, or instead constitute an interdependent system of relations, is an empirical question in particular cases. To the extent that they take each other into account in competitive relationships, enter into various contractual and cooperative undertakings or have recourse to central mechanisms to resolve conflicts, the various political jurisdictions in a metropolitan area may function in a coherent mannerwith consistent and predictable patterns of interacting behavior. To the extent that this is so, they may be said to function as a 'system'. (V. Ostrom, Tiebout, & Warren, 1961, pp. 831–32)

agro-ecological system is more likely to be effective to secure and reinforce farmer's rights (O), the outcome under investigation, and consequently *in situ* conservation and food security. In section 3.1 while discussing the origins of state fragility, it was noted that weak states are most likely to occur where social structures are represented by a "weblike" complexity with high levels political fragmentation and pluralism, resulting in the capacity of "social organisations" to function separately from state institutions (Forrest, 2003). In one hand, this suggests that polycentricity is at the root of state fragility, but on the other hand, there are also more contemporary issues which govern the evolution of the overall governance system in Guinea Bissau that is contributing to a polycentric governance regime. In fact, the governance system *in use* blends a long-standing customary governance system, which entails a level of polycentrality, with new forms of polycentric governance that typically emerge *in situ*ations of state fragility: the so-called governance states (Pureza et al., 2007). Within governance states, while territorial integrity is respected, the international donors and NGOs exercise a high degree of influence on core functions of the state (Pureza, Roque, Rafael, & Cravo, 2007; Barry, 2007). It is worth pointing, that this does not mean this polycentric regime is stateless. It was shown in section 5.2 that decentralized government structures, in particular, INPA-Contuboel is well embedded in the community of lowland farmers. Overall the **governance *in use*** seems to fulfil better the matching principle by better "matching jurisdiction with the scope of a given problem" and therefore the more likely to be cost-effective in dealing with farmers rights' and to incentivise the conservation of agro-diversity. To further investigate which governance system type is more cost effective it is important to discuss the transaction costs associated with these different governance regimes.

Both ***governance in form*** and ***governance in form*** sub-systems are polycentric governance systems which effectiveness on promoting the farmer's rights outcome, depends to a certain degree on **transaction costs associated with these different regimes**. Polycentric governance regimes can also be labelled as a Type II governance regime. However the resilience of these regimes depends to some extent with benefits associated with scale flexibility and the transaction costs associated with coordination (Martin, 2008; Hooghe & Marks, 2003). The multi-scale governance system that characterises all sub-systems *in form* is much more limited in term of scale flexibility in one hand and involves much coordination needs of different actors operating at different levels. Conversely, the polycentric governance system *in use* has a smaller scale, at lower levels and fewer actors resulting in greater benefits associated with scale flexibility and lower transactions costs associated with coordination. The longevity of governance systems is much associated with these transaction costs, making the governance system to use more likely to endure. The greater flexibility and smaller costs associated with the polycentric governance system, is of particular relevance since is this system *in use* that is currently awarding farmers' with seed sovereignty-related rights.

Regarding **historical continuity** (GS10) the governance system *in form* is relatively new when compared to the governance system *in use* that have been in place for long periods. This fact together with the issue of the coordination dilemma expressed above makes that multi-level governance type II regimes more likely to "die" when compared with polycentric regimes involving lower levels and smaller scales. These finds so far provide further evidence to Ostrom's claim that the theoretical presumption stating that only largest scale institutions can deal with global problems is not necessarily true (2010).

One of the most relevant attributes among a community is the ambient levels of **trust and shared norms of reciprocity** (McGinnis & Ostrom, 2014). Trust is a key element underlying economic and social transactions that demand a cooperative and reciprocal behaviour (Ostrom & Walker, 2003). In the previous sections, evidence was provided on the limited trust that the majority of actors operating in the governance system *in use* have on state institutions. This aspect is likely to undermine the prospects of any institutional arrangements involving states structures, particularly at the collective choice level, aiming at enhancing farmers' rights' and protecting agro-biodiversity. The governance system *in form*, in which the state is a critical actor, is less likely to succeed in "passing down" any the aims of governance system *in use* at a meta-constitutional and constitutional level, as a result of the low level of trust between state actors in the governance system *in use*, at collective choice level, and actors in the governance system *in use*. There is a feeble link between these two governance systems, and that link is the state (see section 5.2. on details of trust and reciprocity; section 3.1. on state fragility and rural society).

Evidence of the effectiveness of polycentrality in achieving certain outcomes in particular contexts is well documented. Studies of water industry performance carried out in California during the 1960s, showed that multiple public and private agencies have found productive ways of organising water resources at multiple scales with the presence of multiple government units without a clear hierarchy was found effective (Ostrom, 1965; Weschler, 1968). Research examining the marine areas of the Caribbean found that these are managed through integrated and well-linked resource systems and with multiple beneficiaries were more robust/resilient than systems with greater or fewer linkages (Adger, Brown, & Tompkins, 2005). On management of rangelands in the US which moved closer to polycentricity, with the development of complex networks of actors, and an adaptive system without a single dominant authority, Ostrom (2005) found that citizen groups and coalitions between rangers and environmental groups were successful at developing and enforcing rules to limit grazing, that were locally accepted, while diminishing the levels of conflict. Blomquist and Ostrom (2008) provide a detailed description on how groundwater users in California managed to address problems of extreme water scarcity. Their results show that an adaptive, locally specific, polycentric governance system, was effectively used in Southern California for groundwater governance. Another study on groundwater management in India found that local NGOs and religious organisations were able to effectively work with communities in hundreds of villages to limit groundwater usage and work collectively to recharge groundwater. The approaches used to solve this problem were built on already existing traditional institutions of water management that had been active in these areas for centuries (Shah, 2007).

It **does not mean that polycentrality is a panacea**, there is no assurance that the combination of rules at diverse levels are optimal for any particular outcome (Andersson & Ostrom, 2008). A study in Indonesia on Reducing Emissions from Deforestation and Forest Degradation (REDD+)[110] found that the transactions costs necessary to build cross-level links between institutions might be undermining a participatory multilevel governance, since powerful actors shape the governance system according to their self-interest, and there is limited investment in engaging less powerful organisations (Gallemore, Di Gregorio, Moeliono & Brockhaus, 2015). Also research looking at the effectiveness of a network of actors (Habitat 141°), at multi-levels and different scales in Australia, identified that the complexity involving the governance arrangements was difficult to sustain, and undermined this network's ability to support the necessary functions of coordination and self-organisation critical to polycentric governance (Wyborn, 2015).

Notwithstanding the challenges associated with the effectiveness of a polycentric regime, the characteristics of the polycentric system *in use* suggest that this governance system might be the most appropriate, at least in the short and medium term. More limited number of actors, lower transaction costs associated with coordination and scale flexibility, better match between the scale of the resource and the jurisdiction of the governance system together with higher levels of trust, as described in previous sections, are the key characteristics of this regime. On the whole, this provides a strong indication on how this regime can be effective to full-fill particular outcomes such as farmer's rights, agro-diversity and food security.

[110] a program intended to finance protection of tropical forests through the sale of carbon offsets or from donor funding

Governance Sub-Systems *in form* and Unbalanced Influence (I) towards Farmers Rights (O)

Beyond governance regime, coordination and historical continuity related aspects, contrasting and influencing the effectiveness of the governance systems *in form* and *in use*, there are also other factors that influence the relative effective across the three sub-systems in form: (i) Biodiversity and Farmers Rights', (ii) PVP and (iii) Regional Harmonization.

At the **meta-constitutional level,** there are competing agendas – the farmers' rights and intellectual property rights. The explicit wording and strong enforcement of intellectual property treaties contrast with Farmers' rights, which have the weakest wording and enforcement provisions (Haugen, 2015). Moreover, ITPGRFA leaves to the discretion of states how Farmers' Rights are implemented in their national law. This feature differs from the UPOV system, where the national PVP law of a country is reviewed and approved before granting membership limiting the possibilities of states to adapt PVP laws to individual countries' needs (Christinck & Tvedt, 2015). For farmers´ rights there are no legally binding international standards. However such standards do exist for intellectual property rights (Santilli, 2012). Haugen (2015) also notes developing countries which have been fighting for lower protection standards in of the TRIPS Agreement (Trade-Related Aspects of Intellectual Property Rights) accept high protection standards on the regional and domestic levels. Furthermore, the author notes that actors at the meta-constitutional level are not able to pass down their agenda, suggesting they might need to resort to other institutional arrangements working at lower level jurisdictions to achieve their goals.

At the constitutional level there are no competing agendas. Both PVP and Regional Harmonization agendas at the constitutional level do not have as strong counterbalance of influence towards farmers' rights, as it does at the meta-constitutional level. One example of this is the lack of attention that regional processes of harmonisation have been receiving (Wattnem, 2016). Nonetheless as shown in Section 6.3 the former is in a better position to be implemented at the collective level and applied at the operational level even if on a limited scale. Which is also a result of state's incentive to move forward one agenda over the other[111]. Section 6.3 has also shown that there is larger support regarding capacity building and funds being channelled to the government under the Regional Harmonization agenda when compared to the PVP agenda.

[111] Interviews 8 and 9

Finally, **rules flowing from meta-constitutional and constitutional levels to the collective choice level,** either with a positive or negative potential of affecting seed sovereignty of lowland farmers, are again curtailed by the state fragility situation in Guinea Bissau. Guinea Bissauan farmers have not being profiting from some mechanisms that could improve their livelihoods, preserve the traditional knowledge and enhance agrobiodiversity (i.e. Biodiversity and Farmers' Rights agendas). However, on the other hand, the seed governance system *in use* in Guinea Bissau has been relatively preserved from the *rules in form* that could hamper farmers' *de facto* rights over seeds, such as the ones being pushed forward by the PVP and Regional Harmonization Agendas

In sum, customary practice under the governance system *in use* has been relatively immune to rulemaking in the international arena so far through the governance system *in form,* and it is very likely that it will be kept this way in the short and medium term. Despite pressures to transpose to the national law and enforce potentially harmful rules to farmers' rights, it will be very unlikely. The slow pace in which this process is evolving, and considering that even institutionalisation occurss, it will be with limited strength and scale, altogether it will make unlikely the erosion of farmers' rights.

How can farmers' customary rights over seeds being maintained and reinforced- their right to save, use, exchange and sell farm-saved seed and propagating material – and what their possible way forward in this regard, is discussed in the following section.

7. Conclusion and Policy Implications

This paper's key research questions were: (i) what are the key aspects on international and regional seed governance shaping Guinea Bissau's seed related laws, a country characterized by fragility and limited statehood, which might permanently disturb local, regional and national seed systems, and (ii) how they might affect (either positively or negatively) the sovereignty *de facto* rights and customary practices that characterize the governance system that lowland rice farmers use.

These questions where answered by examining three different governance systems and their respective political agendas, as well as interactions (Interactions) between them, and how these are affecting (or not) lowland farmers' rights (Outcome) in Guinea Bissau. I have found that overall the state of fragility affecting Guinea Bissau, is curtailing any attempt to operationalize international efforts aimed at shaping national seed laws and therefore affecting seed management at an operational level. Farmers' in Guinea Bissau are using the same long-lasting customary practices that rule who and how they save, use, exchange and sell seed in the lowland agro-ecological system. The State is a cornerstone under these international obligations and frameworks since sovereignty over plant genetic resources is recognised at the level of the State. Hence, the state is a central institution to seed sovereignty and security, mediating not only access and benefit sharing between users and providers, but also enforcing plant variety protection and quality control and certification regimes. Without the state none of the *rules in form* being designed at meta-constitutional and constitutional levels will translate into changes for farmers' rights and rules. There is a missing link between the rules made by international and regional organisations and farmers' rules *in use* – that link is the state.

Developing countries with more resources, stronger states and which more are politically stable, are finding it extremely difficult to translate to the domestic level **farmer's rights enshrined in the ITPGRFA and CBA** (Srinivasan, 2003; Halewood, 2016**)**. Implementing farmers' rights in this context requires a state with legislative capacity, with strong and well-coordinated institutions. The PVP and Quality Control and Certification agendas have very clear guidelines which are provided "ready for use", the same does not hold for ITPGRFA and CBA operationalization posing an additional challenge to turn rules aiming at farmer's right reinforcement into practice. Hence, Guinea Bissauan farmers are not benefiting nor their rights' being protected by the rules and funding provisioned under these international treaties and conventions.

The **PVP related rules** are the only rules that can be enforced and are biding in Guinea Bissau at present. The Bangui revised agreement, applies automatically as the national law in each of the OAPI member States, including Guinea Bissau. The predominance of the informal seed systems as the main seed source, coupled with prevailing levels of poverty makes the majority of the rules (e.g. PVP protected varieties use and re-planting) that could potentially undermine farmers rights' rather irrelevant for lowland farmers, with little or no consequences to the seed sovereignty currently experienced by farmers. This irrelevance stems from the fact that for farmers to use illegally these protected varieties, it would assume the existence of a commercial seeds market. However this is not the case for the lowland production system. On the other hand, this institutional weakness means that local seeds could in principle be privatised if "discovered" and, moreover, privatisation could be extended to similar pre-existing varieties. The illegal appropriation of local seeds by the private sector is the chief risk to Guinea Bissau farmers' rights. Guinea Bissauan farmers are vulnerable to bio-piracy in the presence of the regional and international regimes to which they have signed up that are coupled with a gap in national laws, regulations, and a state, that cannot protect farmers'.

The *rules in form* under the **Quality Control and Certification** are the ones more likely to be brought down to the operational level. Notwithstanding all the challenges (e.g. legislative, institutional and financial) for Guinea Bissau to set up a well-functioning quality control and certification system, the close and strong links of the Bissauan governments with ECOWAS and the funds being channelled for this purpose by international donors (e.g. FAO and USAID) make it more likely to be a reality in the mid-term. However, this system, if in place, is very likely to have no or limited impact on the way that lowland farmers' enjoy their rights over seeds.

This chapter has also shown that these global governance systems regulating seeds, overlap, complement each other, but are as well contradictory and with different abilities to influence and push their agenda down to the operational level. A key conclusion from this analysis is that the balance on the ability to influence farmers' rights, either positively or negatively between the different governance sub-systems, results more negative towards farmers' rights and the management of genetic diversity. This is true at the Global level but is even more striking in Guinea Bissau. The Biological Diversity Agenda, on the one hand, is fully concentrated in institutions that do not deal with agriculture in general and farmers' rights in particular. Notably, the Institute of Biodiversity and Protected Areas efforts on the conservation of biological diversity is focused on managing natural/national parks. On the other hand the Ministry of Agricultural and Rural Development, through National Institute of Agrarian Research (INPA), is concentrated and being financially supported to move forward the Regional Harmonization agenda, with little recognition nor incentive (e.g. support by international institutions, funding) to promote agro-biodiversity and protect farmers seed systems, which should naturally fall under its mandate. On the whole, there are no champions nor incentives at the government level to promote *in situ* agro-biodiversity conservation, traditional knowledge nor farmers' rights. Outside the government spheres, support exists despite being limited it lays on civil society organisations that advocate and work with farmers' around these issues.

Finally, and most importantly, this study has shown that there are a number of actors (e.g. Users, Users organisations, Local NGOs, decentralized governance structures), that although fairly disconnected from rulemaking organisations at the global and regional spheres, **are operating at different levels in the governance system *in use*. These actors are devising and enforcing rules *in use* that provide farmers with rights that overlap to a great extent with the Biodiversity and Farmers' rights' agenda.** The reinforcement of the ability of farmers to exercise agency within this polycentric system seems to be the only way forward to lowland farmers' seed sovereignty in Guinea Bissau.

Policy Implications

"'Global solutions' negotiated at a global level, if not backed up by a variety of efforts at national, regional, and local levels, are not guaranteed to work well" (Ostrom, 2010[112]). This claim is particularly relevant in the context of persistent fragility of the state where the interface between the global and the local it is virtually absent. Recurrent political instability, short electoral cycles and high staff turnover in Guinea Bissau, undermines a *de jure* protection and enforcement of farmers' rights that should emerge from state institutions. What opportunities are left for lowland female farmers to promote conservation of genetic diversity, food security and livelihoods under such a complex framework?

Policy implications to be presented will aim to answer the above question at the governance systemas a whole, as well as to providing specific policy recommendations that are more likely to be cost-effective and context specific to the socio-ecological system under analysis. Since farmers experience *de facto* rights' over seeds as "artifacts" and "ideas", more than creating new institutional arrangements there is the need to strength and protect the existent ones, by reinforcing and supporting traditional customary rights and promote collective action at different levels and scales.

Another recommendation would be to strengthen and enhance links between units within the polycentric governance system to cope with collective actions problems pertaining to farmers' rights, traditional knowledge and agro-diversity**.** The theoretical presumption that only largest scale institutions can deal with global problems is not necessarily true (Ostrom, 2010). Other forms of governance emerge can be efficient in solving global collective action problems ranging from climate

[112] Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, *20*(4), 550-557.

change to farmers rights underlying the Biodiversity Agenda. Ostrom (1999) based on extensive empirical research found that although large-scale units are part of the effective governance of metropolitan areas, small and medium-scale units were also necessary. This is of particular relevance in Guinea Bissau, were government level efforts towards farmers rights are very unlikely in the short and medium term. Section 6.1 has shown that despite of the inability of the ITPGRFA and CBA to enforce and effectively promote farmers' rights' there is a polycentric system emerging. In this system, many civil society, traditional authorities and state organisations at the many levels[113] are already promoting and finding out ways to enhance seed sovereignty and local agro-biodiversity at smaller scale and lower levels. An effective approach to promoting farmers rights' will by strengthening this polycentric system, its actors, their links and their interventions. Cross-scale and multi-level networks of resource management can create more resilient governance but also governance that is more participatory and effective if the right incentives are put in place.

One cost-effective way towards strengthening a polycentric approach given the context at hands would be through development projects implemented by development NGOs at the collective choice. These NGOs at the collective choice level, in partnership with operational level community-based organisations, are the best positioned to promote this polycentric approach for several reasons: generally aligned with the principles underlying farmers' rights, can easily access and link with institutions from different scales and at different levels, easy access funds from international donors to promote seed sovereignty for the lowland female farmers. Thus lowering the transaction costs associated with coordination and enhancing scale flexibility. These organisations could focus on initiatives of two types:

(i) Reinforcing the links across the different actors at different levels and scales of the polycentric system *in use*:

- Strengthening and supporting the participation of Bissau Guinean civil society organisations in regional events and coalitions/alliances supporting farmers rights' and farmers seed systems;
- Reinforce civil society coalitions at the national level (e.g. RESSAN) and particularly at the Bafata's regional level (e.g. Coordination Development Committee which matches the scale of the resource system). To raise awareness on farmers' rights, inform on global, regional and national laws and regulations with the potential to undermine these rights;

[113] Constitutional level (e.g. COASP, COPAGEN), collective/national level (e.g. RESSAN, Tiniguena, KAFO, TESE and LVIA), collective/ intermediate level (e.g. GUIARROZ, APALCOFE, CAMPOSSA) and operational level (Users)

- Promote horizontal advocacy networks of farmers at different scales to interact at different governance levels but particularly at the regional level as a priority, to achieve cross-level and cross-scale coordination;

(ii) Specific interventions in the context of the polycentric regime:

- Advocate within government institutions on the importance of farmers seed systems, their role in food security/sovereignty and risks that particular laws and regulations can pose to farmers rights';
- Provide policy recommendations and practical guidance to Guinea Bissau's government on possible leeway to farmers' rights under the Bangui Agreement and the Regional Harmonization processes. The lack of legislative capacity at this moment might offer an opportunity to widen the debate around laws and regulations being prepared. At this point, the difficulties (and incentives) for the Guinea Bissauan government to enact and enforce a Plant Variety Protection laws are low. These are likely to be even lower towards a *sui generis* (IPR-based farmers' rights) system provisioning farmers' rights. However, this does not mean these cannot be provisioned elsewhere, namely in other legal instruments, such as the Seed Policy and other related legal documents, currently under discussion.
- Advocate and provide recommendations to make *de jure* the rights of women farmers as stewards of agro-diversity, seed and food security, in the context of the Seed policy and related legal instruments;
- Since a clear division between formal and informal seed systems was not found, interventions should aim at strengthening complementarity practice between the more "formal"[114] research (e.g. INPA Contobuel) and smallholder farmers to improve the livelihoods of smallholder farmers and climate resilient seed systems. Take advantage of the partnership Africa Rice centre (CGIAR) to promote exchanges of genetic resources into and out of Guinea Bissau for agricultural research and development. In one hand, promote the effective participation of farmers from different agro-ecological contexts, particularly the ones in more marginal environments, in the processes of participatory varietal selection being introduced in Guinea Bissau, to promote the adoption of higher quality and more suitable varieties. On the other hand, promote the reinforcement and integration of local varieties and associated traditional knowledge into the formal research system (See Chapter 2 and 3 for more detailed policies implications with this respect).

[114] "formal" because INPA in Contuboel operates in a way that cannot be considered as purely formal

- Gain a deeper understanding of agro-biodiversity status and management by lowland communities and promote community biodiversity management interventions specifically designed to meet practical needs at the operational level and aligned with local institutional logics. Study the feasibility of the existing community seed banks to become not only seed as artifacts facilities but as well facilities for seeds as ideas.

A final recommendation is an alert on the risks that development projects might bear to farmers in the lowland socio-ecological system. It is important to be aware that strengthening farmers' rights is not a synonym of ensuring women's rights. Therefore any intervention being currently developed and implemented (e.g. African Development Bank, LVIA, TESE), needs to carefully address the incentives these projects create that can change the rules *in use*. Development partners need to ensure that these interventions should not unintentionally erode females' rights concerning land (See section 5.2) and the related bundles of rights' they currently enjoy regarding seeds.

One of the key limitations of this study was the lack of data on agro-biodiversity in general, and particularly related to lowland rice in Guinea Bissau, to provide a better context regarding one of the key aspects underlying farmers' rights. Also a more in-depth understating of traditional knowledge associated with crop diversity management would provide a broader picture of the implications of farmer's rights to the maintenance and management of agro-biodiversity.

Concerning future research, this study has found some areas that would be important to explore in order to provide a deeper understanding on how some development interventions might influence the rules currently *in use* and where not extensively covered in this research. Investigate the extent to which the dynamic of seed aid prevailing in the region might: (i) be constraining the possibility of income generations activities related to seed production and widening seed access options for lowland female farmers (See Chapter 2 and 3 on the limited market for seeds), (ii) changing social norms and customary practice involving seeds. Many development projects have implemented cereal/seed banks as a key measure to deal with seed insecurity. It would be important to assess the extent to which these facilities are actually having an impact on food security outcomes in beneficiary villages and again how these projects might be changing social norms and customary practice involving seeds. Finally, there is a very limited understanding of the quality of the seeds the farmers use, despite conflicting evidence (See chapter 3 Section 2.1) on the quality of seeds. It would be important before claiming the quality advantage of using the certified seed to have more detailed knowledge on the local varieties flowing within the polycentric governance system-

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Appendix I. Meta-constitutional, constitutional and Collective Actors and Rule Making Organisations

FAO	• Supports the Harmonized Seed Regulation in West Africa process through ECOWAS/CILLS/UEMOA (CORAF, USAID & ECOWAS, 2014) • Third Party Beneficiary under the ITPPGR: Third Party Beneficiary is an entity designated by the Governing Body of the International Treaty and which acts on behalf of the Governing Body itself and the Multilateral System to ensure observance of the contractual terms and conditions of the Standard Material Transfer Agreement (SMTA) by the individual providers and recipients[115]
USAID	• Funds the West Africa Seed Program (WASP). (CORAF, USAID & ECOWAS, 2014)
EU	• Launched in 2015 by the European Union, the EU-AINDA Program - Integrated Actions in Nutrition and Agricultural Development, is supporting the implementation a number of rice promotion projects through grants support to projects promoted by international and local non/governmental organisations. Under this context funds to see related projects (See below TESE and LVIA)
African Development Bank	• The African Development Bank (AfDB) and the Government of Guinea-Bissau signed in early 2017 a € 5.7 million financing agreement to develop the Rice Value Chain Development Project in the Regions of Bafatá and Oio. Among the bank's program activities is the strengthening of access to certified seeds and quality inputs and setting up a revolving fund for the procurement of inputs (fertilizers and seeds). Both projects aim, through different aid delivery approaches, to strengned the rice seed sector, in Guinea Bissau (AfDB, 2017).
International Treaty on Plant Genetic Resources for Food and Agriculture	• The International Treaty on Plant Genetic Resources for Food and Agriculture was adopted by the Thirty-First Session of the Conference of the Food and Agriculture Organisation (FAO) of the United Nations on 3 November 2001. • The Governing Body is the highest organ of the Treaty as established in Article 19. Composed of representatives of all Contracting Parties, its basic function is to promote the full implementation of the Treaty, including the provision of policy guidance on the implementation of the Treaty. • The Governing Body holds regular sessions at least once every two years. The decisions are taken by consensus unless it is decided (by consensus) to employ another method to arrive at decisions on certain measures. Consensus is always required

[115] http://www.fao.org/plant-treaty/areas-of-work/the-multilateral-system/operationalization/en/

Governing Body[116]	for amendments of the Treaty and its annexes. The Governing Body adopted its Rules of procedures at its first session in Madrid.
Conference of the Parties Convention on Biological Diversity (CBD)[117]	• The Convention on Biological Diversity (CBD) is an international legally-binding treaty with three main goals: conservation of biodiversity; sustainable use of biodiversity; fair and equitable sharing of the benefits arising from the use of genetic resources. Its overall objective is to encourage actions, which will lead to a sustainable future. • The CBD's governing body is the Conference of the Parties (COP). This ultimate authority of all governments (or Parties) that have ratified the treaty meets every two years to review progress, set priorities and commit to work plans.
GRAIN[118]	• GRAIN is a small international non-profit organisation that works to support small farmers and social movements in their struggles for community-controlled and biodiversity-based food systems. Our support takes the form of independent research and analysis, networking at local, regional and international levels, and fostering new forms of cooperation and alliance-building. Most of our work is oriented towards, and carried out in, Africa, Asia and Latin America.
BEDES[119]	• BEDE (Biodiversity: Exchange and Diffusion of Experiences) is an international solidarity association founded in 1994. Contributes to the protection and the promotion of farmers' agriculture by supporting the initiatives of a management respectful of living by a work of information and networking, in connection with about fifty organisations of different networks French, European and International. • Organizes workshops, meetings between peasants, researchers and civil society from European, Maghreb and West African countries, supports the structuring of farmers' organisations and produces teaching materials. This work allows the general public to grasp the issues, and farmers and organisations to improve both their fieldwork and their legislative bargaining abilities. • Supports COPAGEN and COASP
ASFA[120]	• Pan African platform comprising networks and farmer organisations working in Africa including the African Biodiversity Network (ABN), African Centre for Biodiversity (ACB) Coalition for the Protection of African Genetic Heritage (COPAGEN),

116 http://www.fao.org/plant-treaty/overview/governing-body/it/
117 http://www.un.org/en/events/biodiversityday/convention.shtml
118 https://www.grain.org/pages/organisation
119 https://www.bede-asso.org/qui-sommes-nous/
120 http://afsafrica.org/pt/home/what-is-afsa/

	Comparing and Supporting Endogenous Development (COMPAS) Africa, Friends of the Earth- Africa, Indigenous Peoples of Africa Coordinating Committee (IPACC), Participatory Ecological Land Use Management (PELUM) Association, Eastern and Southern African Small Scale Farmers' Forum (ESAFF), La Via Campesina Africa, FAHAMU, World Neighbours, Network of Farmers' and Agricultural Producers' Organisations of West Africa (ROPPA), Community Knowledge Systems (CKS), Plate forme Sous Régionale des Organisations Paysannes d'Afrique Centrale (PROPAC), Global Justice Now, Tanzania Alliance for Biodiversity, INADES-Formation, Rural Women's Assembly (RWA), Groundswell Africa and Fellowship of Christian Councils and Churches in West Africa (FECCIWA). • AFSA was launched at the UN Framework Convention on Climate Change (UNFCCC) Conference of Parties 17 (COP 17) in Durban, South Africa in December 2011. • ASFA Challenged African leaders on Climate Change through a declaration in November, 2009 signed by the following organisations: African Biodiversity Network (ABN); African Centre for Biosafety (ACB); Coalition for the Protection of African Genetic Heritage (COPAGEN); Comparing and Supporting Endogenous Development (COMPAS); Eastern and Southern African small scale Farmers' Forum (ESAFF); GRAIN;m Indigenous Peoples of Africa Co-ordinating Committee (IPACC); Participatory Ecological Land Use Management (PELUM) Association
EU-WEST AFRICA-ECOWAS-UEMOA[121]	• West Africa and the European Union (EU) concluded in February 2014 the negotiations for an Economic Partnership Agreement (EPA). • The agreement is the first Economic Partnership that brings together not only the 16 countries of the region but also their two regional organisations: the Economic Community of West African States (ECOWAS) and the West African Economic and Monetary Union (UEMOA).
OAPI	• The Organisation Africaine de la Propriété Intellectuelle or OAPI (English: African Intellectual Property Organisation) is an intellectual property organisation, headquartered in Yaoundé, Cameroon. The organisation was created by Bangui Agreement of March 2, 1977. The Bangui Agreement was subsequently amended in 1999. • Annex X in the revised agreement, certified by UPOV council, as complying with UPOV 1991, establishes a regional plant variety protection (PVP) regime applicable to the 17 members of OAPI

[121] http://trade.ec.europa.eu/doclib/docs/2014/july/tradoc_152694.pdf

African Union	• All the African states except Morocco are currently members of the African Union, which was first established as the Organisation of African Unity (OAU) in 1963 and launched as the African Union in 2002.[122] • The African Model Legislation for the Protection of the Rights of Local Communities, Farmers and Breeders, and for the Regulation of Access to Biological Resources has relevant provisions on farmers' rights, namely in: Part 1. Objectives, Part 4. Community Rights, Part 5. Farmers` Rights[123]
ECOWAS/CILLS/ UEMOA	• The processes harmonized regional seed policy in the Sub-Saharan Africa started in 1998 at Abidjan, Cote d'Ivoire, and resulted in the establishment of the African Seed Network. This gave place to consultative process held in Dakar and Lome in 2004 which launched the development of the regional seed policy and regulation by stakeholder • With the support of FAO, the Economic Community of West African States (ECOWAS) have undertaken the harmonization of national seed regulatory frameworks in their respective Member States. The regional harmonization focus on technical issues such as Seed quality assurance, Variety release, Plant quarantine and phytosanitary measures, Plant variety protection to provide incentives to plant breeding, give farmers access to more varieties and reduce the costs of protection and Biosafety. The ECOWAS Commission, in its quest to create favorable conditions for cooperation and pooling of resources, decided to entrust to CORAF/WECARD, the coordination and animation of the West Africa Seed Committee, for a transitional period of five years. The choice of CORAF/WECARD was based on its proven expertise and skills already mobilized for implementing the West Africa Seed Program (WASP). The West Africa Seed Committee (WASC/COASem-CRSU) may be regarded as the engine for driving the emergence of a strong seed industry within the ECOWAS-UEMOA-CILSS region. ECOWAS, UEMOA and CILSS, following Abidjan understood the complexity of implementing separate regulations, decided to move towards the use of a common approach in implementing the Harmonized Regional Seed Regulation. This was done in two stages: firstly, between ECOWAS and UEMOA, and secondly, between ECOWAS-UEMOA and CILSS. The establishment of a Unique ECOWAS-UEMOA-CILSS West Africa Seed Committee was an important step in the implementation of the Harmonized Seed Regulation in West Africa. (CORAF/WECARD, 2014)
COASP	• Comité Ouest-Africain des Semences Paysannes (COASP) • The West African Peasant Seed Committee (COASP) was formed following the 3rd West African Farmer Seed Fair in Djimini in November 2011.

[122] https://au.int/
[123] http://www.wipo.int/edocs/lexdocs/laws/en/oau/oau001en.pdf

	• The delegates of the countries of the sub-region decided to set up this committee to "consolidate the exchange of information on peasant seeds and the laws that threaten them"
COPAGEN	• Coalition for the Protection of African Genetic Heritage (COPAGEN) • COPAGEN comprises a membership of farmers' organisations, trade unions, women organisations, youth groups, academics, NGOs in ten countries; Benin, Burkina Faso, the Gambia, Guinea Bissau, Guinea Conakry, Mali, Niger, Senegal, Togo, and the Ivory Coast. • COPAGEN advocates adopting policies that promote biosafety and food sovereignty in our subregion, supporting member states in the preparation and adoption of an appropriate legal framework. • COPAGEN works on the following issues: GMOs, farmers' rights, land issues, agrofuels, agricultural policies and food sovereignty. (AFSA, 2009)
Regional Seed Related Organisations/Programs	• There are a number of West Africa regional level seed related governance organisations. • The West Africa Seed Alliance (WASA) purported to ensure that farmers have affordable, timely and reliable access to seed and other planting material of improved, adapted crop varieties. • CORAF/WECARD through West Africa Seed Program (WASP) to support actions for sustainable production and use of quality seeds of major staple crops, particularly cereals in West Africa. The WASP is also coordinating the establishment of the Alliance for Seed Industry in West Africa (ASIWA) and the West Africa Seed Committee (WASC/COASem). Supported by USAID, a great focus of this programme is to push forward the ECOWAS Seed harmonization regulation efforts across the region (CORAF/WECARD, 2014)
Ministry of Agriculture-INPA	• The Ministry plays a key role in the relationship between the coordinating institution and INPA, in the field of research, in the follow-up of activities and in establishing relations with partners in the rice sector. In general, this Ministry is responsible for: a) Definition of legal framework of production; b) Definition of the action plan; c) Creation of hydro-agricultural infrastructure and availability of inputs and agricultural equipment through projects financed by financial institutions, technical partners as well as NGOs in specific geographic areas, often coordinated by MADR; d) Acquisition and availability of processing equipment; (e) construction and provision of community warehouses for the storage of surplus or cereal banks INPA • The National Institute of Agrarian Research, shortly designated as INPA, is a body with legal personality, administrative and financial autonomy, and its own patrimony and under the supervision of the Ministry of Agriculture and Rural Development.

	• INPA, aims to carry out and coordinate agrarian research, to support the rural and agro-industrial agrarian development of Guinea-Bissau. It is important to note that INPA since 1998 has lost its administrative and financial autonomy, which means that it depends only on sub-regional projects to function. • The Mandate of INPA: Participation in the elaboration of the National Policy of Agrarian Research; Execution of all elements arising from it; Coordination of all agricultural research activities in Guinea-Bissau, both in the public and private sectors. In order to carry out its mandate, the following functions are assigned to INPA in the research area: (a) development of sustainable agriculture based mainly on the protection, conservation and renewal of natural resources; b) Development of technology appropriate to the different groups of farmers in the country; c) The carrying out of economic and socio-economic studies related to the agricultural sector and the rural environment; d) The carrying out of inventories and studies of the natural resources of the sector; e) To conduct programs of vegetal and animal breeding (EU, 2015)
IBAP	The Institute of Biodiversity and Protected Areas (IBAP) was established by Decree 2/2005, under the Minister in charge of the Environment, this establishment has administrative, financial and patrimonial autonomy, and therefore has the capacity to develop policies and norms related to the conservation of biodiversity. Its mandate is essentially to propose, coordinate and implement the policy and actions pertaining to biodiversity and areas protected throughout the national territory. This institute is therefore responsible for the management of parks and the management and monitoring of the key values of biodiversity (species and habitats) in Guinea-Bissau. To foist a new dynamic in international agreements to which Guinea-Bissau is committed, (with particular relevance to the CBD and its Protocols), the director of IBAP was appointed as focal point of this Convention. In 2012 other technicians at this institution were to be appointed to take on the responsibility for the national reports and positions as Focal Points such as Nagoya Protocol on Access and Benefit-sharing. (RGB, 2014)
RESSAN[124]	▪ Civil Society Network for Sovereignty and Food and Nutrition Security in Guinea-Bissau ▪ Has 52 members including Guiarroz, KAFO, Proagri and Tiniguena ▪ Their mission is to contribute to the realization of the Human Right to Adequate Food and the Promotion of Food and Nutritional Security and Sovereignty in a sustainable way in Guinea-Bissau.
TESE[125]	▪ Portuguese NGO

[124] http://www.ressan-gb.gw/
[125] http://www.tese.org.pt/index.php/atuacao

	▪ Implementing “Resilience Reinforcement Project in the Rice Sector” in the Bafatá and Contuboel Sectors, in partnership with the Guinean NGO Guiarroz. ▪ Project’s main outcomes are to: Establish decentralized irrigation systems, powered by solar energy, replacing thus diesel, and managed through a participatory model; To create financial products for agricultural development with the purpose of amortizing shocks caused by climate change; To address the development of the rice sector with the exchange of knowledge among farmers.
LVIA[126]	▪ Italian NGO ▪ Implementing “No Intchi Mbemba – Reforço da fileira de sementes de arroz” which is working with smallholders in the development of seed production and storage funded by EU AINDA
COPAGEN-GB[127]	COPAGEN has branches in all countries of West Africa and Tiniguena is its focal point for Guinea Bissau. Together with the Peasant Federation KAFO and the Consumer Protection Association (ACOBES), they coordinate the Guinean antenna, COPAGEN-Guinea-Bissau, which has 21 members. The issue of land grabbing and the safeguarding of traditional seeds were adopted as COPAGEN-GB's priority and unifying themes.
Tiniguena[128]	Tiniguena, an organisation in Guinea-Bissau dedicated to the preservation of biodiversity through citizen action and cultural emancipation. The name Tiniguena means this land is our land in the local Cassanga language Promote a project Kil ki di nos ten balur - loosely translated as "what we have is priceless" - Tiniguena is working with seed savers to recover local varieties, and to multiply and distribute the best seeds. By organizing a yearly "Eat National Day" they are also building demand and appreciation for local produce in urban citizens and farmers. Farmers who recognize the true value of their seeds are less likely to be lured by agribusiness and their patented seeds that eat at high prices. Just as importantly, citizens who appreciate locally grown food are precious allies to farmers. Tiniguena is also focal point of COPAGEN in Guinea Bissau
Kafo[129]	The KAFO Peasant Federation was established in 1996 and officially registered as a national non-profit association (NGO) in December 2000. Its headquarters is in Djalicunda, Mansabá sector, Oio region (Guinea Bissau). The record of registration was published in Official Gazette no 50 of 11/12/2000, providing the 10 federated peasant associations federated by the federation constituting KAFO with

[126] http://www.lvia.it/paese/guinea-bissau
[127] http://www.tiniguena.org/page25.html
[128] https://interpares.ca/news/protecting-biodiversity-and-building-food-sovereignty-guinea-bissau
http://www.redsan-cplp.org/membros-ressan-gb.html
[129] http://guineabissau.sodepaz.org/federacao-camponesa-kafo/show

	legal basis. With the core mission of Community Self-Promotion and Sustainable Rural Development, the KAFO Peasant Federation supports processes to strengthen personal and organisational skills that ensure local people are involved in defining and implementing their development options. Approximately 23,454 peasants and peasants benefit directly from the interventions of the KAFO Federation in more than 900 plots located in the north and northeast of the country (Oio, Cacheu and Bafatá Regions). In order to reinforce the technical and organisational capacities of the peasants, the KAFO Federation has established a Center for Peasant Training, Agricultural Vulgarization and Valuation of Traditional Knowledge. The Center serves as a meeting point for civil society organisations in Guinean and state institutions, and serves as an ideal framework for carrying out actions of socio-cultural exchange among peasants, development education, information and communication via community radio, gender promotion and leadership of women in the rural world.

Other Regional Organisations

There are a number of West Africa regional level seed related governance organisations. The West Africa Seed Alliance (WASA) purported to ensure that farmers have affordable, timely and reliable access to seed and other planting material of improved, adapted crop varieties. CORAF/WECARD through West Africa Seed Program (WASP) to support actions for sustainable production and use of quality seeds of major staple crops, particularly cereals in West Africa. The WASP is also coordinating the establishment of the Alliance for Seed Industry in West Africa (ASIWA) and the West Africa Seed Committee (WASC/COASem). Supported by USAID, a great focus of this programme is to push forward the ECOWAS Seed harmonization regulation efforts across the region.

Appendix II. First and Second-tier variables of a social-ecological system

First Tier	Second Tier
Social, economic, and political settings (S)	S1 – Economic development S2 – Demographic trends S3 – Political stability S4 – Other governance systems S5 – Markets S6 – Media organisations S7 – Technology
Resource systems (RS)	RS1 – Sector (e.g., water, forests, pasture, fish) RS2 – Clarity of system boundaries RS3 – Size of resource system RS4 – Human-constructed facilities RS5 – Productivity of system RS6 – Equilibrium properties RS7 – Predictability of system dynamics RS8 – Storage characteristics RS9 – Location
Governance systems (GS)	GS1 – Policy areas, GS2 – Geographic scale of governance system, GS3– Population, GS4 – Regime type GS5 – Rule-making organisations, GS6 – Rules-in-use GS7 – Property-rights systems. GS9 – Network structure GS10 – Historical continuity
Resource units (RU)	RU1 – Resource unit mobility RU2 – Growth or replacement rate RU3 – Interaction among resource units RU4 – Economic value RU5 – Number of units RU6 – Distinctive characteristics RU7 – Spatial and temporal distribution
Actors (A)	A1 – Number of relevant actors A2 – Socioeconomic attributes A3 – History or past experiences A4 – Location A5 – Leadership/entrepreneurship A6 – Norms (trust-reciprocity)/social capital A7 – Knowledge of SES/mental models A8 – Importance of resource (dependence) A9 – Technologies available
Action situations: Interactions (I) → Outcomes (O)	I1 – Harvesting I2 – Information sharing I3 – Deliberation processes I4 – Conflicts I5 – Investment activities I6 – Lobbying activities I7 – Self-organizing activities I8 – Networking activities I9 – Monitoring activities I10 – Evaluative activities

	O1 – Social performance measures (e.g., efficiency, equity, accountability, sustainability) O2 – Ecological performance measures (e.g., overharvested, resilience, biodiversity, sustainability) O3 – Externalities to other SESs
Related ecosystems (ECO) ECO1 – Climate patterns	ECO2 – Pollution patterns ECO3 – Flows into and out of focal SES

Source: Adapted from Ostrom (2009:421) and McGinnis and Ostrom (2014)

Appendix III. Local Seed Varieties and Improved Varieties

Variety	Freq.	Percent	Cum.
Wancaram	189	25.75%	26%
Bani Malo	119	16.21%	42%
Santanto	55	7.49%	49%
Carsia	43	5.86%	55%
Poropotchi	40	5.45%	61%
Mistura	34	4.63%	65%
Djunqueme	33	4.50%	70%
Otchocoro	21	2.86%	73%
Folere	18	2.45%	75%
Acobolo	15	2.04%	77%
Maro Wodeo	13	1.77%	79%
Adulai	12	1.63%	81%
Mobal	11	1.50%	82%
Salimaru	9	1.23%	83%
Tabadjenque	8	1.09%	84%
Djunoro Queba	7	0.95%	85%
Ussumane	7	0.95%	86%
Iama Gullel	6	0.82%	87%
Ngregade	6	0.82%	88%
Bissau	4	0.54%	89%
Djunorowuda	4	0.54%	89%
Muna Djau	4	0.54%	90%
Nhada	4	0.54%	90%
Bantaliama	3	0.41%	91%
Farumata	3	0.41%	91%
Malicoio	3	0.41%	91%

Nerica	3	0.41%	92%
Nhima Malo	3	0.41%	92%
Bafata	2	0.27%	93%
Braima Dabo	2	0.27%	93%
Cefa	2	0.27%	93%
Cuboli	2	0.27%	93%
Darodara	2	0.27%	94%
Djundjiguile	2	0.27%	94%
Maro Bissau	2	0.27%	94%
Nani	2	0.27%	94%
Naru	2	0.27%	95%
Suntu Male	2	0.27%	95%
Tchamoel	2	0.27%	95%
Auael	1	0.14%	95%
Binta Basse	1	0.14%	96%
Buducu	1	0.14%	96%
Danfalamalo	1	0.14%	96%
Djamaram	1	0.14%	96%
Djambarandim	1	0.14%	96%
Djonhindim	1	0.14%	96%
Eleldu	1	0.14%	96%
Manfatu	1	0.14%	96%
Mariama Seidi	1	0.14%	97%
Mariba	1	0.14%	97%
Marina Seide	1	0.14%	97%
Maro Aua	1	0.14%	97%
Maro Auo Umel	1	0.14%	97%
Maro Baleo	1	0.14%	97%
Maro Sandugo	1	0.14%	97%
Midjo	1	0.14%	98%

Mobahaba	1	0.14%	98%
Morel	1	0.14%	98%
Nhaba	1	0.14%	98%
Nhadala	1	0.14%	98%
Nhalalalon	1	0.14%	98%
Quenemo	1	0.14%	98%
Rabagenque	1	0.14%	99%
Ranewo	1	0.14%	99%
Sambaro	1	0.14%	99%
Senquerem	1	0.14%	99%
Sudjur	1	0.14%	99%
Sumtu Male	1	0.14%	99%
Tembedere	1	0.14%	99%
Tubacuta	1	0.14%	99%
Uma Oio	1	0.14%	100%
Wombo Hulem	1	0.14%	100%
Woyo Coro	1	0.14%	100%
Yuncalancam	1	0.14%	100%
Total	**734**	**100**	

Source: Data collected by the author Contuboel Survey 2015

Table 9 Varieties Introduced past 10 years

Centres du MADR	Nombres de variétés introduites pendant 10 dernières années (riz)	Région	Ecologie	Provenance des variétés	Année d'introduction
Contuboel/INPA	31	Bafata	Bas-fonds (irrigué)	AfricaRice	2010
	49		Plateau	AfricaRice	2013
Caboxanque/INPA	99	Caboxanque	Mangrove	AfricaRice	2011
	27		Mangrove	AfricaRice	2013
	99		Mangrove	AfricaRice	2014
Carantaba	5	Gabu	Bas-fonds (irrigué)	Mission chinoise	2010

Source: MDRA FAO (2015)

Appendix IV. PVS Process in Guinea-Bissau

Despite of this process being dubbed as PVS it is important to notice that in a framework of methods of varietal selection with varying degrees of farmer participation the right terminology for the approach carried by INPA would be Researcher-managed and evaluated on-station trials, where farmers could visit station to identify farmer-acceptable material (A. Joshi and J.R. Witcombe). The PVS methodology encompasses one essential criteria that was not met in the approach carried out by INPA that is the selection by farmers on their own fields. One of the objectives of PVS as alternative to a top-down transfer of technology model is accelerating the dissemination of preferred crop varieties for smallholder farmers in marginal environments (Pandit, 2008; Bourai et al., 2004; Rawal et al., 2008, Virk et al., 2003, Witcombe et al., 2003, 2007, Walker, 2008). Despite of promoting the participation of farmers in the station trial, these trials were held at conditions that are very difficult to replicate at most of the farms in the region, namely access to irrigation infrastructures and the use fertilizers. Is a question of concern that some of the selected varieties for multiplication might not adapt to farms at different environments and underperform in the criterion that justify their selection on-station.

Appendix V. Interviews List

Interviewee #	Name	Organisation	Location	Date
1	Buarou Baldé	Regional Directorate of Agriculture	Bafatá	October 2014
2	Luis Có	National Research Agricultural Research Institute INPA-Contuboel Research Center,	Contuboel	October 2014
3	Malam Mane	Guiarroz	Contuboel	October 2014
4	Sambel Baldé	Proagri	Bafatá	October 2014
5	Antonieta Angela Gomes Fernandes António Nassau and	APALCOFE	Contuboel	October 2014
6	Janqué Mané and Malam Ibras Sissé	Agro-multipliers Association	Contuboel	October 2014
7	Samoel Mendes	TESE Associação para o Desenvolvimento	Bissau	January 2018
8	Amadu Uri	Guiarroz	Contuboel	January 2018
9	Malam N'Bari Sissé	APALCOFE	Contuboel	January 2018
10	Adja Djenabu Baldé	Agro-multipliers Associaton	Contuboel	January 2018

Chapter 5. Conclusion

This **research focused on lowland rice producing areas in the east of Guinea-Bissau**. Rice has long been the main food staple in many traditional rice growing communities and in major cities in West Africa, and Guinea-Bissau is no exception. From the early 1970s, rice has been the main source of caloric intake in West Africa (Chuhan-Pole & Angwafo, 2011). Beyond its cultural value, rice in Guinea-Bissau contributes to 62% of cereal production and 75% of cereal consumption (Diakité, Djata, & Rodrigues, 1997). This research used as a case study the lowland production systems in Bafatá, which is located in east Guinea Bissau, where rice production is the principal economic activity for the majority of the region's women. The context of lowland rice production provided a suitable setting to research the issues at hand - namely seed systems, security, and sovereignty.

The **main motivation for this study** was threefold. First, it results from a deep recognition of the critical role of women as food providers, innovators, and stewards of agro-biodiversity of rice in the east region of Guinea Bissau. Second, to see how the limited understanding of the functioning of these farmers' seed system, seed security, and sovereignty can determine the development of relevant interventions in the seed sector, with unintended consequences for households' food security. Thirdly, to contribute to the knowledge and understanding in the fields of seed security and seed sovereignty, with the objective of creating more effective policies and interventions and of progressing the academic fields of research which are covered in this study.

The **main research objective of Chapter 2** is to develop a comprehensive seed security measure - the Seed Security Index, to address the shortcomings identified in the literature review. This index summarised in a single measure the five dimensions of seed security at household level, namely: access, availability, quality, varietal suitability, and resilience. The method employed to compute the Seed Security Index and to estimate the alternative indices was principal component analysis with polychoric correlations. The results provided evidence that the variables selected to construct the index resulted in a reliable measure for representing the latent phenomena of seed security. Furthermore, the results also indicated that engendering the index by including gender-specific, rather than non-gender specific variables resulted in a more reliable index by better reflecting the intra-household gender dynamics and their role in seed security. The Seed Security Index is a measure of farmers who perform simultaneously well across all dimensions, ranging from availability through to farmers' social and economic access, through to seeds and resilience. However, by placing these results in the particular context of the study area, it was found that although economic-related indicators are a theoretical expression of seed security, in practice, women do not make use of this access and resilience sub-dimensions, as the market for seeds is absent. For this reason, three seed security indices where obtained from the multivariate analysis approach. The first is the theoretical Seed Security Index - which identifies those seed-security farmers who experience higher (or lower) levels of seed security simultaneously across all variables, irrespective of the particular seed security dynamics which are experienced in a particular context. The second are two additional seed security indices from the first and second principal components, which represent context-specific and complementary forms of seed security, namely: i) the Biodiversity and Social Capital Index - which captures the biodiverse, marginal environment, and aid recipient type of seed-secure farmer/area, and; ii) the Availability, Social Access, and Utilisation Index - which identifies a type of seed-secure farmer/area who is experiencing unconstrained availability, which is more socially connected to seed organisations, works with seeds of greater quality and are more suitable for their environment and preferences. Finally, this chapter examins the differences between two groups - seed secure and seed insecure, for the different types of seed security, pointing out the key characteristics of households, farmers, and farms for each type of seed security, which can increase the predictive power of identifying vulnerability. This analysis helps, not only to improve the understanding of the informal seed system in general, but also the phenomena of lowland rice seed insecurity, particularly in Guinea Bissau.

The **research objective of Chapter 3** is to gain a deeper understanding of the mechanisms underlying seed security and its relationship with food production and food security, by answering the following research questions: (i) What are the determinants of seed security?; (ii) What are the mechanisms underlying the relation between seed, food production, and food security? and; (iii) What is the effect of seed security on food production, and consequently on food security?. The determinants of seed security were estimated through three models specifications, namely: Ordinary Least Squares, Village Level Fixed Effects, and Random Effects. To examine the mechanisms underlying the relationship between seed security, food production, and food security, I carried out an in-depth literature review. Finally, to estimate the effect of seed security on food production and as the treatment (seed security) is a continuous variable, I used a generalised propensity score matching to estimate a dose-response function. This chapter also shows that land, labour, and experience are consistent determinants across the three measures of seed security under analysis. Finally, the results have shown that greater seed security leads to increased food production, at least at moderate to high levels of security, and they also suggest the causal pathways through which that effect occurs'.

Chapter 4's research objective is to contribute to a broader and comprehensive understanding of the Guinea Bissauan lowland socio-ecological seed systems and to identify the potential challenges and opportunities brought about by global and regional policies and laws which affect female farmers' rights in this context. To this end, I answered the following research questions: (i) How do international and regional seed governance regimes shape Guinea Bissau's seed-related laws, being a country which is characterised by fragility and limited statehood?; (ii) What rules and rights emerging from these systems are affecting, or are likely to affect lowland female farmers' rights, with consequences for agrobiodiversity and food security? The research hypothesis of this paper is that the Plant Variety Protection (PVP) and Regional and Harmonization agendas have a detrimental effect on the rights that farmers are currently enjoying with respect to seeds, while the international governance system, which focuses on farmers' rights and biodiversity, could reinforce these rights. This hypothesis was tested by employing the Socio-Ecological Systems frameworkas as the analytical framework for the analysis, which is a recent outcome of Ostrom's Institutional Analysis and Development (IAD) framework. I found that overall, the limited statehood in Guinea Bissau undermines any attempt to operationalise international efforts aimed at shaping national seed laws, which therefore affects seed management at an operational level. Farmers in Guinea Bissau using the same long-lasting customary practices that determine the rules which govern who uses seed, and how they save, use, exchange, and sell seed in the lowland agro-ecological system. Notwithstanding the *de facto* rights enjoyed by lowland farmers, the uneven balance between proponents of farmers' rights on one side, and the defendants of PVP and Regional Harmonisation certifications regimes on the other, this might pose a risk to the status quo of seed sovereignty, with consequences for their livelihoods and agro-biodiversity. This study also shows that the governance system in use is characterised by polycentrality. The sustainability of these rights rests on the ability of farmers to exercise and reinforce their agency within this polycentric system.

The findings of this thesis have provided **policy recommendations** for effective interventions aimed at improving seed security, seed sovereignty, and ultimately food production and agro-biodiversity. In this study I present policy implications of the different chapters, while providing insights of the synergies among regarding more effective interventions.

Chapter two points to different policy interventions according to the particular types of seed Security. The Seed Security Index can identify farmers who perform well (or worse) in all seed security variables simultaneously. The more seed-secure farmers or areas are, under this measure, they are those who are more suitable to be targeted for seed market-oriented interventions, especially by promoting agro-multipliers roles into *de facto* seed commercial producers. The study site context suggests this is likely to be a more effective approach, considering the high levels of poverty among farmers, particularly female ones, and the persistent state of government instability, which are all likely to undermine the development of the formal seed sector, in particular the private sub-sector, or at least in the short and medium term. Under this measure, seed insecurity should be dealt with by both seed and development-oriented interventions, as, given the particular context that it represents for both eed insecurity and wealth measure. Regarding seed insecurity under this measure, the results suggest that seed insecurity must be dealt with by both seed and development-oriented interventions, as based on this particular context, it can be said to be a combination of seed insecurity and a wealth measure. Particularly with respect to availability, social access, and utilization, the seed-specific issues embedded in this index represent interventions which should be targeted at improving availability at the farm level, thus improving social and geographic access to seed-surplus areas, such as Contuboel and also access to higher quality and more suitable varieties. Examples of availability interventions include promoting irrigation and the planting area through increased mechanisation and the use of sustainable fertilisers and high yielding varieties. In order to improve availability to more geographically-isolated farmers, broader development policies are required to promote rural integration. Increased social access can be achieved by promoting network-based interventions to tackle the social inclusion of marginalised farmers, and seed fairs, which can both be critical in improving social (and economic) access to seed in general, and also variety suitability and diversity among these farmers. Finally, to address low seed quality and less-preferred varieties, interventions should be favoured which improve seed quality and promote access to varieties with more desired traits of seed insecurity, such as participatory plant breeding, participatory varietal selection, and targeted programmes. The policy implications with regards to the **Availability, Social Access, and Utilisation Index** are similar to those presented to cover the seed-specific dimensions of the Seed Security Index.

Finally, the **Biodiversity and Social Capital Index** captures those seed-secure farmers who have higher levels of varietal diversity and who are more socially engaged with information-providing organisations. The most seed-secure farmers, although they are more likely to have a more diverse varietal portfolio, they fit the profile of the more marginal farmers, who are those who are better suited for participatory plant breeding and participatory varietal selection interventions. Availability, quality, and varietal suitability can all be promoted through the intervention of INPA-Contuboel and other partner organisations in a two-way approach. In one way, these organisations can work with farmers towards increasing yields and production, through the use of higher quality and more suitable varieties. However, at the same time, these interventions can be used to promote the integration of existing local diversity in the formal sector and to work to improve their quality and the dissemination of the associated indigenous knowledge. The existence of local diversity also suggests that interventions should focus on promoting the existing in situ diversity conservation of locally-preferred varieties, namely through gene banks. Seed-insecure farmers require similar types of interventions, although targeted to other issues. These farmers have a limited choice of varieties, with specific traits in the local system, and therefore diversity can be enhanced through the promotion of in situ conservation, such as community seed banks or local gene banks. Furthermore, seed fairs linking farmers with greater varietal diversity to others who have a more limited portfolio is also a type of intervention which can prove to be effective in supporting farmers towards greater agro-biodiversity, and consequently, to be more resilient. Nonetheless, before reinforcing a policy to increase the scale of the implementation of seed banks, some preliminary studies need to be carried out. Accordingly, the feasibility of turning the existing community seed banks into not only seed or artefacts facilities, but also into facilities for seeds as ideas should be assessed, as should carrying out an evaluation of the performance of the existing seed banks (see Section 5.2 - Chapter 4 for details on the existing seed banks). Regarding practical application, is it worth noting that the general approach presented in this chapter is context-independent. Despite the components and respective weights being context-specific, this approach is suitable for being replicated and tested elsewhere, and it stands to serve as a tool that can support governments and agricultural organisations in particular to elaborate policies, and formulate and target interventions in the seed sector.

Chapter 3's findings on the determinants of seed security mirror the low-level maturity of the formal seed sector experienced by lowland farmers in Contuboel sector. As income-related variables do not seem to have a role in seed security, particularly through access, this translates into that factors of production, with land, labour, and experience being the main determinants of seed security across all measures. Beyond these determinants, for both Seed Security and the Biodiversity and Social Capital indices, female-headed households were found to be negatively-associated with seed security. Conversely, farmers belonging to the Mandinga ethnic are more likely to be seed-secure, under both measures. Regarding the Availability, Social Access, and Utilisation Index, unlike the other indices and contrary to previous research, the results have shown that both belonging to a female-headed house and greater perception over tenure insecurity increases the probability of households being seed-secure.

On the whole, the policy recommendations provided in Chapter 2 are critical for tackling the different forms of seed insecurity that farmers are currently experiencing in the study area. The results of the determinants summarised above reinforce the findings of Chapter 1 that income-related variables are neither structural, nor intermediary determinants of seed security. The absence of a seed market, as discussed in more detail in Chapter 4, is likely to be in part a result of the dynamics of the seed aid delivered by government institutions, which could curtail the opportunity of agro-multipliers to become *de facto* seed producers to supply local markets. Measures to support these farmers become more commercially-oriented producers and reinforce the value chain by linking them to local markets and general traders, could offer additional sources of seed, while enhancing the seed security prospects of lowland farmers. Notwithstanding the economic limits of female farmers to access to commercial certified seeds, the results suggest that policies aimed at removing the inefficiencies which have been brought about by some interventions will have the potential to create local markets for lowland rice seeds.

Furthermore, this study has presented evidence of the potential shift in farming practices (e.g., young women losing interest in rice farming - see Chapter 4 - Section 5.1), of the importance of the rice farming experience (see Chapter 3 and 4), and of the shortcomings of the formal seed systems in providing a diversified portfolio of seeds (see Chapter 4). These aspects suggest an opportunity for the national agricultural research institution (INPA) to work collaboratively with female farmers to capture, maintain, and diffuse local knowledge, in order to conserve agrobiodiversity and broaden the genetic base in breeding, namely through participatory plant breeding. Furthermore, these organisations can increase farmers' access to improved and higher-yielding varieties, which will make rice production a more attractive activity for younger female generations, together with complementary interventions to construct and rehabilitate irrigation infrastructures and to extend mechanisation.

Furthermore, the findings regarding the importance of female farmers' experience suggest that research and policy approaches must be gender-sensitive (recognising the body of expertise in some locations lies with female farmers) and must be inclusive of indigenous knowledge and culture in order to be able to effectively inform practices and policies. All these different aspects are likely to enhance food production, as the positive effect of seed security on rice production was also found. In this respect, the key policy implication is that seed security should be an integral part of broader food security policies, given the evidence provided for the role of seed security in increasing food production, and ultimately achieving food security.

In **Chapter 4**, I argued that more than creating new institutional arrangements, there is a need to strengthen and protect the existent institutional arrangements, by reinforcing and supporting traditional customary rights and by promoting collective action at different levels and scales which are embedded in the polycentric system *in use*. Furthermore, farmers' rights are a sufficient, but not a necessary condition for rice diversity and associated knowledge. Therefore, another policy recommendation is to strengthen and enhance links between units within the polycentric governance system *in use* to cope with collective action problems pertaining to farmers' rights, traditional knowledge, and agro-diversity. On the whole, the implementation of all the policy recommendations provided in the previous chapters could be more effectively institutionalised if through the polycentric governance system *in use.*

A summary of recommendations for future research is presented as follows.

Regarding data on seed security (**Chapter 2**), future research can further refine the index to define a core set of variables which, ideally, wouild be based on data which is commonly available across national and local contexts, in order to establish a common approach that can be widely applied. **Chapter 3** pointed out that future research on the determinants of seed security and the effect of seed security on food production could gain from a richer set of variables - particularly with respect to varietal suitability and quality, where more variables would allow the construction of dimension-specific sub-indexes to investigate specific determinants of different dimensions, as well as to further disentangle the effect of specific dimensions on food production. In addition, the use of temporal data would be instrumental for dealing with identification problems that arise from possible sources of endogeneity, but which also provide insights into the dynamics underlying seed security, food production, and food security. In particular, panel data is useful for examining the effect of dimension specific sub-indexes and their effect on mean, variance, and skewness of production. These results also suggest female-headed households and negative perceptions over risk of expropriation to be positively associated with seed security in its availability, social access, and utilisation dimensions. Furthermore, the results suggest that belonging to a specific ethnical group (the second largest) is positively associated with seed security. As these results differ from those of previous research, understanding the possible mechanisms behind them should also be the subject of future research.

Finally, chapter 4 suggests some areas that would be important to explore in order to provide a deeper understanding of how certain development interventions can influence the rules currently *in use*. Accordingly, future research should also focus on the extent to which the dynamics of seed aid prevailing in the region could be: (i) constraining the possibility of income generation activities related to seed production and widening seed access options for lowland female farmers (See Chapter 2 and 3 on the limited market for seeds) and also, (ii) changing social norms and customary practice involving seeds. Many development projects have implemented cereal/seed banks as a key measure to deal with seed insecurity, however it is also important to evaluate how these facilities actually have an impact on food security outcomes in beneficiary villages, and again how these projects are changing social norms and customary practices involving seeds.