Farmers' perspectives on intensive rice cultivation: a participatory diagnosis of practices, constraints, and co-constructed solutions in the middle Senegal River Valley

Abstract

Achieving rice self-sufficiency under a changing climate remains a major challenge for Senegal and requires the sustainable intensification of irrigated rice production in the middle Senegal River Valley (SRV). This study aimed to diagnose current farming practices, identify the main constraints affecting rice production, and propose context-specific improvement options through a participatory approach. The study was conducted in 2020 and 2021 in six villages of middle SRV (Niangua Diéri, Ndiawar, Guia, Kodith, Niandane, and Ngaolé). It combined participatory workshops involving researchers and key stakeholders with field surveys assessing the management of irrigation schemes and rice production practices. The surveys covered irrigation infrastructure, water management, fertilizer use, mechanization, and crop management practices.The results revealed major constraints to rice production include the poor condition of irrigation infrastructure, inadequate maintenance of canals and pumping systems, inefficient water distribution and plot-level water management, weed infestation, bird damage, declining soil fertility, and high irrigation costs. Fertilization relied predominantly on urea (46% N) and diammonium phosphate (DAP), reflecting farmers' dependence on subsidized mineral fertilizers, while the use of organic amendments remained limited. The participatory diagnosis also highlighted deficiencies in fertilizer and irrigation management, particularly non-compliance with recommended fertilizer application rates and irrigation water depths. The study identified several promising improvement options, including improved fertilizer management, better organization of water distribution, strengthened technical support to enhance compliance with recommended agronomic practices, rehabilitation of irrigation infrastructure, and the adoption of more fuel-efficient pumping systems. These findings demonstrate the value of participatory approaches for identifying locally adapted innovations that can contribute to the sustainable intensification of irrigated rice systems in the middle SRV.

Keywords:

Middle Senegal River Valley; irrigated rice; production constraints; participatory diagnosis; irrigation management; soil fertility.

Introduction

Rice occupies a central place in Senegalese diets, with annual per capita consumption averaging 110 kg (USDA, 2021). In 2022, national paddy production reached 1,346,146 tons, equivalent to roughly 838,000 tons of milled rice (DAPSA, 2020), covering only about 40% of the estimated 2,138,000-ton domestic demand for milled rice that year. This left a deficit of approximately 1.3 million tons, met through imports, and placed Senegal as Africa's third-largest rice importer, behind Nigeria and Côte d'Ivoire(FAO, 2021).

Given population growth of around 3.1% per year (FAO, 2022), closing this gap has become a national priority. To reduce import dependence, the Senegalese government has launched several policies and programs, including the Great Agricultural Offensive for Food and Abundance (GOANA) and the National Rice Self-Sufficiency Program (PNAR). With support from the Senegalese Institute for Agricultural Research (ISRA) and the National Society for the Development and Exploitation of the Senegal River Delta and Valleys (SAED), these initiatives have expanded irrigated areas and improved farmers' access to machinery, improved varieties, and technical guidance. As the country's leading rice-producing region, accounting for approximately 60–70% of national rice production (JICA, 2014), the Senegal River Valley (SRV) has been a major recipient of these investments, notably through the development of irrigation infrastructure and the distribution of motor-pump units, the Senegal River Valley (SRV) has been a major recipient of these investments, notably through the distribution of motor-pump irrigation units.

Despite these efforts, rice production gains have remained modest and below expectations (Bruckmann, 2018). Average yields of 4–5 t ha^{-1} fall well short of the 8–12 t ha^{-1} potential of cultivated varieties (Poussin et. 2006; Niang et al., 2017), a gap driven by a combination of biotic and abiotic constraints (Balasubramanian *et al.*, 2007). Prior studies point to weed pressure, bird damage, and poor water management as major limiting factors(De Mey, Demont and Diagne, 2012; Diagne *et al.*, 2013; Djaman *et al.*, 2017; Mballo, R *et al.*, 2018), compounded by declining soil fertility from poor nitrogen management, limited input access, low mechanization, restricted use of certified seed, and weak crop management overall (Bado, Aw and Ndiaye, 2010; Diagne *et al.*, 2013; Niang *et al.*, 2017).

In the middle SRV specifically, these constraints are further compounded by prolonged crop cycles and a low rate of double-cropping on the same plots. Tackling these issues requires a clearer understanding of farmers' perceptions and current practices. It is within this context that the present study was conducted as part of the WAGRINNOVA project ("Co-construction with stakeholders of innovations to strengthen sustainable intensification, resilience, food and nutrition security in water-managed agroecosystems in West Africa"), funded through the LEAP-Agriprogramme. The study was carried out between 2020 and

2021 in six major rice-producing villages in the Middle Senegal River Valley: Niangua Diéri, Ndiawar, Guia, Kodith, Niandane, and Ngaolé. It aimed to (i) identify the main constraints perceived by farmers, (ii) document existing farming practices, and (iii) co-construct consensus-based solutions with farmers to improve rice production.

I. Materials and methods

I.1. Characteristics of the study area

This study was conducted in the middle Senegal River Valley (SRV), which extends from Waoundé to the confluence of the Senegal and Doué rivers (Diop, 2008). Six villages served as study sites: Niangua Diéri, Ndiawar, Guia, Kodith, Niandane, and Ngaolé (Figure 1). The area's population is predominantly Peulh (approximately 90%) (Diop, 2008), with agriculture as the main economic activity and primary source of householdincome.

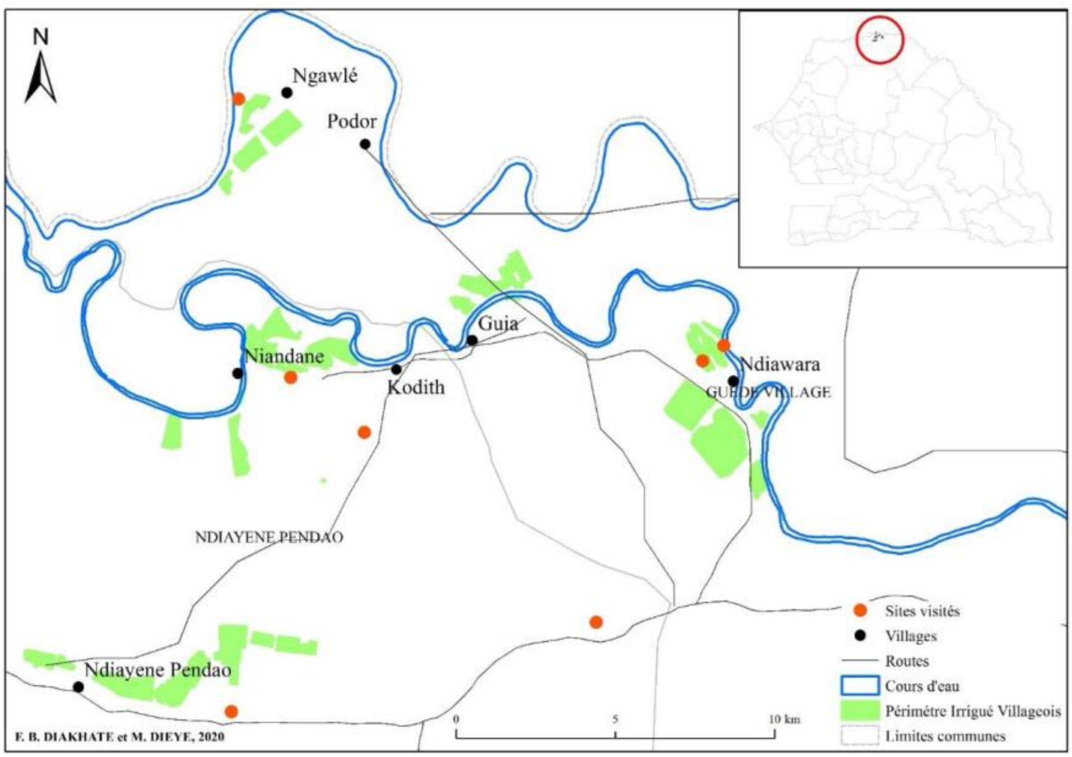

Figure 1 : Carte et localisation de la zone d'étude (SALL, 2023)

The study area has a Sahelian climate marked by a short rainy season and a long dry season, itself divided into a cool and a hot period. These conditions support three rice-growing seasons: wet season (July–October), cool dry season (November–February), and hot dry season (March–June).

I.2. Data collection

The study adopted a co-construction approach involving farmers in two successive phases: participatory workshops with farmers and researchers, followed by a complementary individual survey of the participating farmers.

I.2.1. Participatory workshops

Co-construction workshops were conducted with 23 rice farmers across the six study sites: Niangua Diéri, Ndiawar, Guia, Kodith, Niandane, and Ngaolé. Each workshop began with a brainstorming session to identify the main constraints affecting rice production. Participants then scored each constraint on a five-point scale using stones, where 1 indicated the lowest level of importance and 5 the highest; the score assigned by the majority of participants was retained as the final score for each constraint. Constraints were then prioritised based on these scores and the scope of the project's intervention, leading to the identification of three major constraints.

The same participatory approach was used to co-develop potential solutions, integrating farmers' proposals with those suggested by the project.

I.2.2. Individual surveys of producers

Following the workshops, an individual survey was conducted to further investigate the identified constraints and their underlying causes. Owing to financial constraints, a homogeneous purposive (judgemental) sampling strategy was adopted. A total of 60 farmers were surveyed: 30 on the organisation and collective management of irrigation schemes, and 30 on plot-level water management and rice cultivation practices. The survey covered farmer organisation, cropping systems, production infrastructure, and input supply and management.

I.3. Data processing and analysis

Survey questionnaires were designed using Sphinx version 4.5 (2006) and pre-tested with five farmers prior to data collection. Collected data were processed and analysed using Microsoft Excel 2016 (Microsoft Corporation, 2015), which was also used to generate tables, figures, and graphs.

II. Results

II.1. Identification of constraints

Farmers identified several constraints to rice production, spanning the entire production system: farmer organisation, irrigation infrastructure, input supply, crop management, and harvesting operations (Table 1). Across all study sites, the most severe constraints (each scoring the maximum of 5) were poor irrigation infrastructure, deteriorated canals, and high irrigation costs. Soil degradation was also considered a major constraint, cited by 91% of farmers and assigned the highest importance score. Weed infestation, though identified by all farmers (100%), received a lower importance score of 3. Insect pests and diseases, by contrast, were perceived as relatively minor, with only 52% of farmers scoring them at 3.

Table 1: Farmer-perceived constraints to intensive rice production in the middle Senegal River Valley.

Constraint	Score*	Farmers reporting the constraint (%)
Ageing irrigation infrastructure	5	100
Poor access roads for transporting harvested products	3	65
Degradation of irrigation canals	5	100
Untimely availability of agricultural inputs	4	87
Limited access to high-quality seed	4	78
Insufficient technical skills for diesel pumps	4	100
Non-compliance with the cropping calendar	3	100
Inappropriate motor pumps and frequent breakdowns	4	100
Poor water management	3	78
High irrigation costs	5	100
Inadequate soil amendment practices	4	86
Poor land levelling	2	100
Soil degradation	5	91
Weed infestation	3	100
Bacterial diseases, seedling mortality, and other pests	3	52
Damage caused by granivorous birds	4	100
Damage caused by roaming wild animals, particularly warthogs	4	65

*Constraint importance was scored during participatory workshops on a scale from 1 (least important) to 5 (most important). Percentages represent the proportion of farmers identifying each constraint**.**

II.2. Co-constructed solutions with the WAGRINNOVA project

Several solutions were proposed to address the identified constraints (Table 2). Among those co-developed with farmers through the WAGRINNOVA project, training on motor pump maintenance and organic manure use was the most frequently recommended, cited by all participants (100%). This was followed by land re-levelling and plot compartmentalisation to improve water management on sloping fields, proposed by 91% and 87% of participants, respectively. The least frequently proposed solutions were potassium fertiliser application in rice cultivation and compliance with recommended irrigation water and fertiliser rates, cited by only 9% and 4% of participants, respectively.

Table 2: Proposed solutions to the major constraints affecting intensive rice production in the middle Senegal River Valley

Constraint	Proposed solution	Farmers proposing the solution (%)*
Insufficient technical skills of pump operators	Training of pump operators	100
Poor water management	Training on irrigation scheduling (water rotation)	65
High irrigation costs	Coupling irrigation pumps with the ZS 1115 engine	100
Inadequate soil amendment practices	Training on the importance of farmyard manure for maintaining soil fertility	100
Poor land levelling	Plot compartmentalization using field bunds	87
	Re-levelling fields after initial flooding	91
Soil degradation	Application of organic amendments and potassium fertilization	9
	Soil testing to optimize fertilizer recommendations	43
Weed infestation, particularly by wild rice (*Oryzabarthii*), locally known as "Naaré"	Compliance with recommended herbicide application rates	9
	Maintaining the recommended water depth during herbicide application	4
Bacterial diseases, seedling mortality, and other pests	Avoiding excessive urea application	22
	Use of potassium-containing NPK fertilizers	30

*****_The percentages indicate the proportion of farmers who proposed each solution during the participatory workshops. Several solutions could be proposed for the same constraint; therefore, percentages do not sum to 100%._

II.1.2. Prioritisation of constraints

Three major constraints emerged from the prioritisation process (Table 3), high irrigation costs, weed infestation, and soil degradation, cited by 100%, 100%, and 91% of participants, respectively. Farmers and other stakeholders in the rice sector then co-developed solutions to address each of these priorities.

Table 3:Priority production constraints and proposed mitigation measures identified through the participatory workshops.

Priority constraint	Participants (%)	Proposed solutions
High irrigation costs	100	• Training on irrigation scheduling • Coupling irrigation pumps
Weed infestation	100	• Application of recommended herbicide rates • Proper water depth management
Soil degradation	91	• Soil testing to optimize fertilizer • Application of NPK fertilizer

II.2. Surveys: Description of production systems

II.2.1. Classification and condition of irrigation schemes and pumps

The survey identified three main types of hydro-agricultural schemes (HAS) in the middle SRV: large-scale irrigation schemes (GA), village irrigation schemes (PIV), and private irrigation schemes (PIP) (Figure 2). Private irrigation schemes were the most common, particularly in Niandane, Guia, and Ndiawar, whereas large-scale irrigation schemes were relatively scarce.

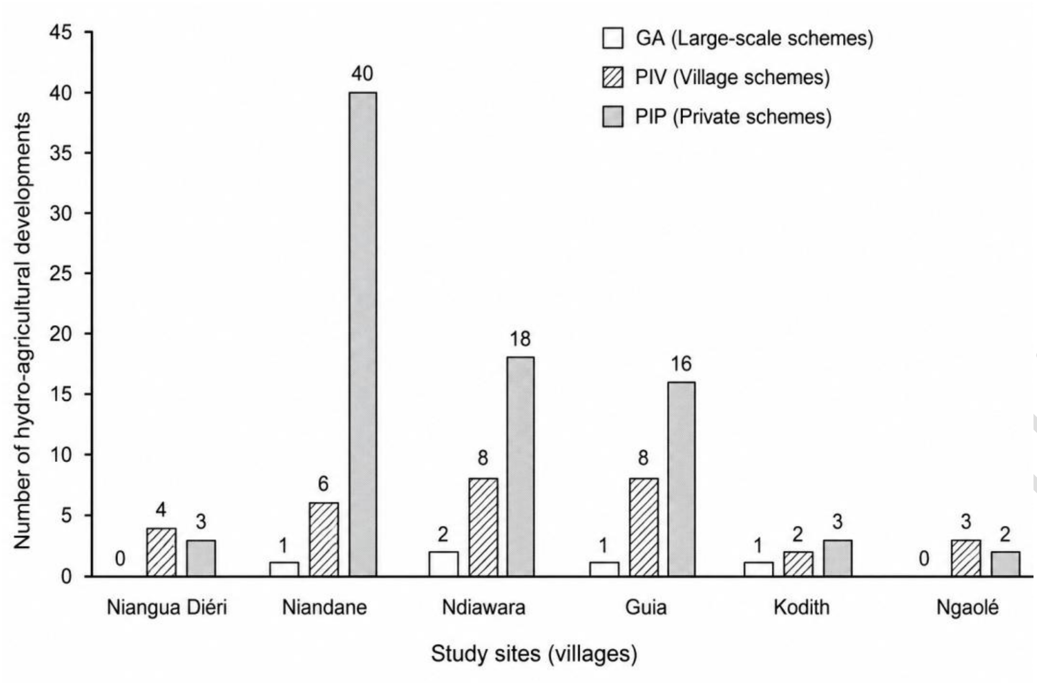

Figure 2: Types of irrigation schemes by study site

Within these schemes, land was allocated to households in 58.3% of cases and to individual farmers in 41.7% of cases. Irrigation water was supplied through diesel-powered motor pumps (MP), electric pumps (EP), and electric pumping stations. The survey further revealed that 75% of the irrigation schemes and 60% of the pumps were in poor operating condition, while only 25% and 15%, respectively, were reported to be in good condition (Figure 3).

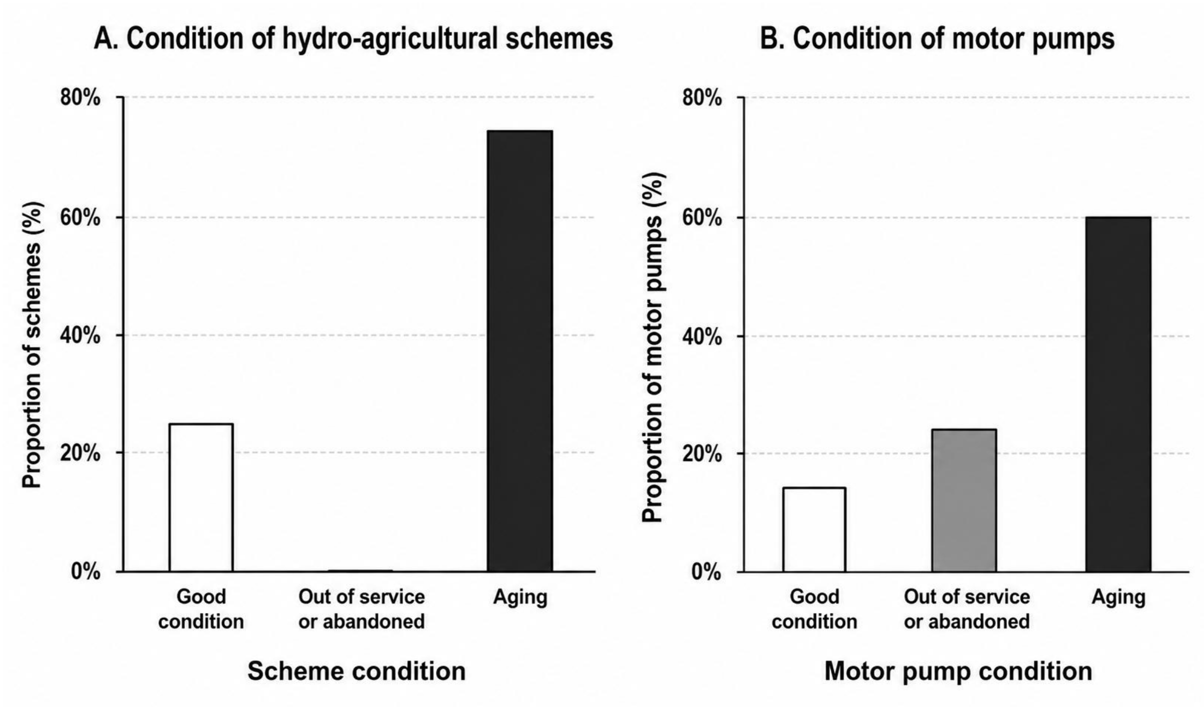

Figure 3: Condition of irrigation schemes and motor pumps

II.2.2. Irrigation networks, water distribution and irrigation-related costs

Irrigation networks are primarily composed of a headrace canal, whose length varies with the size of the irrigated scheme, and a distribution network consisting of a main canal and secondary canals. Water distribution is ensured through water control structures, present in 66.7% of irrigation schemes and Economic Interest Groups (EIGs), operating according to either a downstream-to-upstream or an upstream-to-downstream sequence along the irrigation canal.

Irrigation costs range from 90000 to 140000 CFA francs/ha, averaging approximately 100000 CFA francs/ha. About 42% of respondents paid between 90000 and 110000 CFA francs/ha for access to irrigation water, while only 25% incurred costs below 90000 CFA francs/ha (Figure 4). These variations reflect differences in irrigation management practices, infrastructure characteristics, and operating costs across schemes.

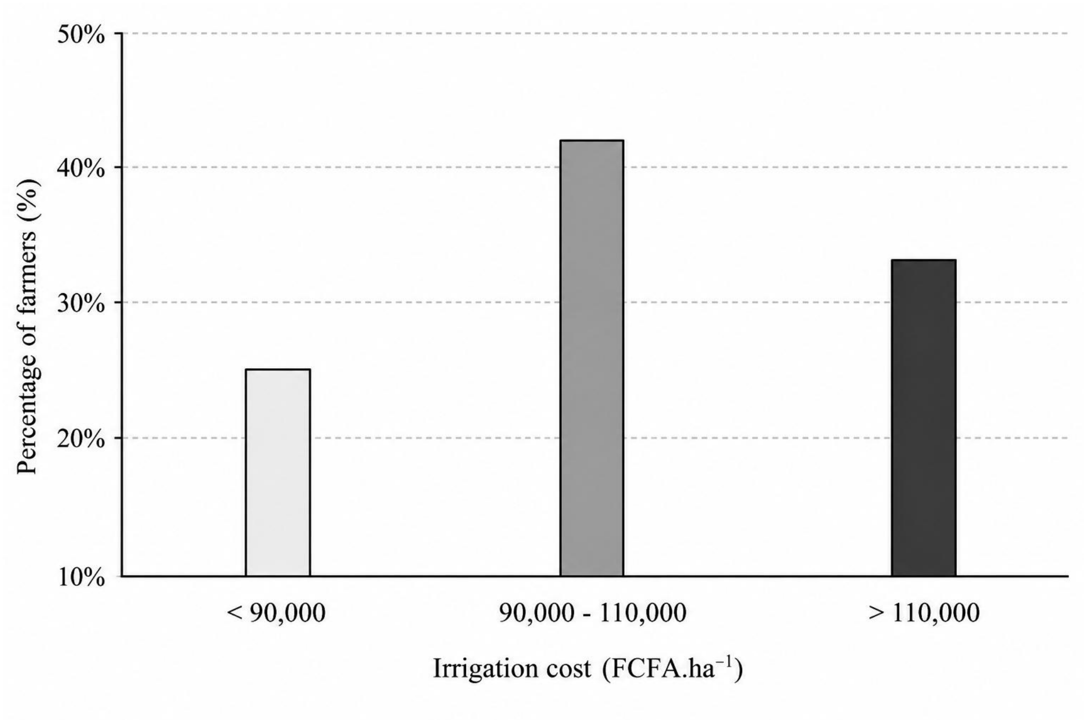

Figure 4: Distribution of irrigation costs

II.2.3. Land preparation practices

Land preparation consists exclusively of tillage using a disc harrow, carried out in one or two passes depending on the farmer's resources. The first pass is covered by the cooperative, while the second is financed by the farmer according to their financial capacity. More than half of surveyed farmers (58.3%) reported paying for a second pass to obtain a finer seedbed. Consequently, within the same irrigation scheme, some plots receive a single tillage pass while others undergo two, reflecting differences in farmers' financial resources and management practices.

II.2.4. Age group and farming experience of producers

In the study area, rice farming is practised across all age groups (Figure 5). The dominant group was 40–60 years, representing more than 70% of respondents in four sites (Niangua Diéri, Ndiawar, Kodith, and Ngaolé), while farmers aged 60 and above formed the second-largest group, accounting for more than 50% of respondents in Guia and Niandane.

Rice farming experience ranged from less than 5 years to more than 40 years. The most experienced farmers were found in Guia, Niandane, and Ngaolé, where 100%, 80%, and 60% of producers, respectively, had at least 40 years of experience.

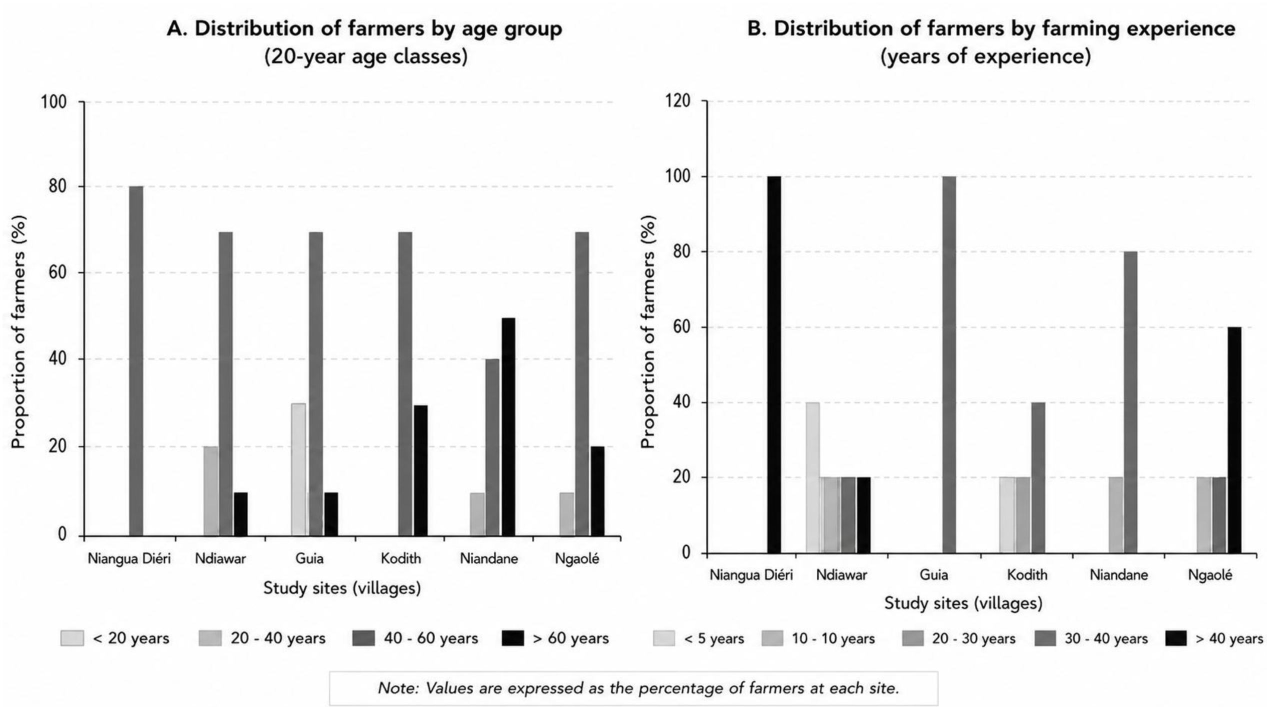

Figure 5: Distribution of rice farmers by age group across the study sites

II.2.5. Growing seasons and crops

The study area is characterised by three cropping seasons: hot dry, rainy, and cold dry. The main irrigated crops are rice, onion, tomato, and okra. All surveyed farmers cultivated rice; among them, 63% also grew onion, 43% tomato, 20% okra, and only 10% other crops, including maize, chilli pepper, and both bitter and sweet eggplant (Table 4).

Table 4: Major crops cultivated by surveyed farmers and their main uses

Crops grown	Cropping seasons	Farmers (%)	Main use of harvested produce
Rice (*Oryza sativa* L.)	HDS and WS	100	Household consumption
Onion (*Allium cepa* L.)	CDS	63	Sale
Tomato (*Solanumlycopersicum* L.)	CDS	43	Sale
Okra (*Abelmoschusesculentus* L.)	CDS and WS	20	Sale
Other crops: maize (*Zea mays* L.), chilli pepper (*Capsicum annuum* L.), bitter eggplant (*Solanumaethiopicum* L.) and sweet eggplant (*Solanummelongena* L.)	CDS and WS	10	Sale; household consumption and windbreak use in the case of maize

HDS: Hot Dry Season, **WS**: Wet Season, **CDS**: Cold *Dry Season*

II.2.6. Input application rates

The two fertilisers commonly used in rice cultivation were urea (46% N) and diammonium phosphate (DAP), applied at similar rates regardless of cropping season. Application rates ranged from 191 to 500 kg/ha for urea and from 0 to 161 kg/ha for DAP (Figure 6).

Rice seeding rates ranged from 90 to 300 kg/ha. For weed control, application rates of the propanil–weedone herbicide mixture ranged from 0.75 to 8.33 L/h.

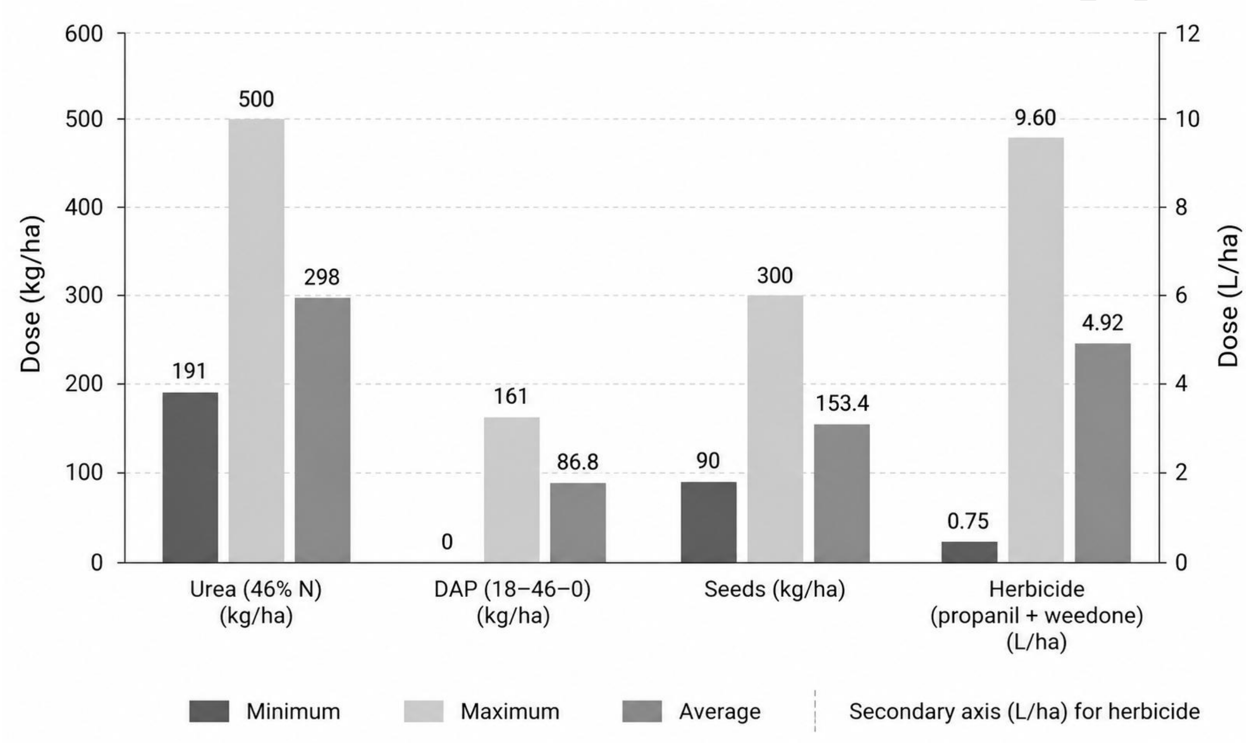

Figure 6: Fertilizer application rates

II.2.7. Water depth management

Water depth during fertiliser application ranged from 0 to 20 cm. Most farmers (73%) maintained a depth of 6–15 cm, whereas only 4% applied fertiliser under 15–20 cm of water (Figure 7).

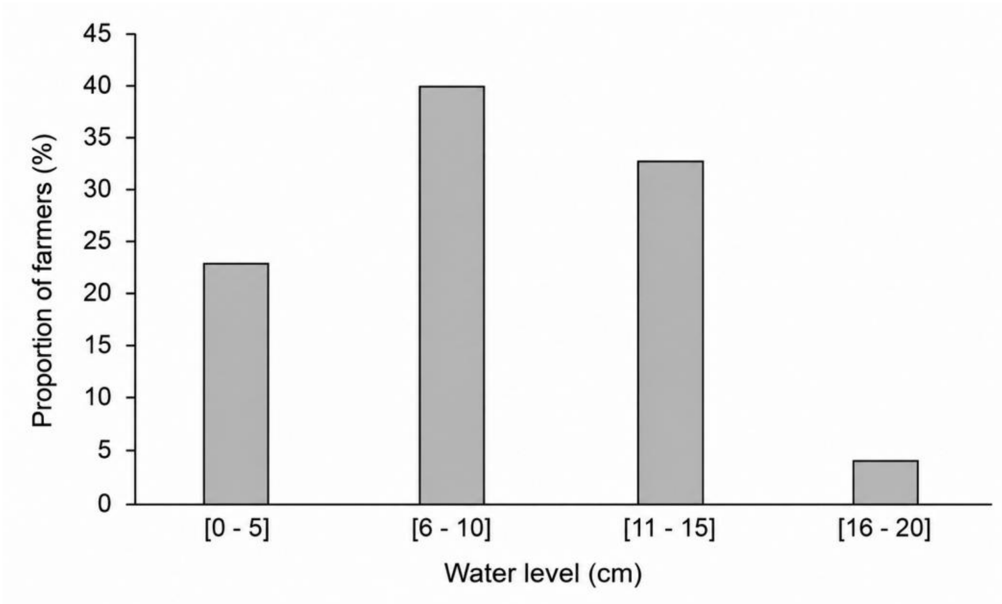

Figure 7:Water depth during fertilizer application

III. Discussion

The workshop findings highlight the constraints farmers face in rice cultivation and in achieving satisfactory yields in the middle valley. Obtained through a co-constructive approach, these results show that inclusive research enables a better understanding of production constraints and supports the identification of appropriate solutions. This perspective aligns with Vall *et al.*(2016), who emphasise that farmers are not merely beneficiaries of research outputs but key actors in the research process. Similarly, Koutou and Vall (2010) report that farmer involvement facilitates both the identification of constraints and the development of context-specific solutions.

Soil erosion caused by rainfall and livestock grazing is identified as the main driver of infrastructure degradation, affecting irrigation and drainage channels as well as access tracks. Heavy rainfall events, combined with grazing pressure during the dry season, contribute to the collapse of earthen channels, a situation worsened by the fact that many schemes have not been rehabilitated since their establishment in the 1970s (Sakurai, 2023), a constraint also noted in institutional assessments of irrigation development in the Senegal River Valley (SAED *et al.*, 2011). Moreover, much of this infrastructure was originally built in a relatively rudimentary manner (Diemer and Laan, 1987; Boivin, Pascal, Favre, Fabienne, and Maeght, Jean-Luc, 1998; Poussin *et al.*, 2003), leaving significant levelling defects that farmers often attempt to correct through re-levelling during the initial flooding phase at the start of the cropping season (SAED *et al.*, 2011).

Soil degradation and the risk of seedling blight appear to result from insufficient soil amendment practices, continuous rice cultivation on the same plots, and the widespread removal of crop residues, particularly rice straw, for livestock feed. This latter practice was highlighted by Poussin *et al.*(2003), who linked residue removal to the development of livestock systems in the Senegal River Valley, thereby intensifying nutrient export from cultivated fields.

The removal of crop residues from fields contributes to a decline in soil fertility, particularly through potassium depletion. This is consistent with Unger *et al.*(1991), who emphasised that soil conservation (in terms of both structural stability and fertility) depends largely on the retention of crop residues and their incorporation into the soil through appropriate tillage. Similarly, Bado, Djaman and Mel(2018) underline the importance of annual potassium application to sustain adequate fertility in rice-based systems, given potassium's key role in regulating physiological and biochemical processes within the soil–plant system; indeed, potassium is widely recognised as critical to rhizosphere functioning, supporting multiple metabolic and enzymatic processes. In this context, the removal of rice straw and stubble, if not compensated by external nutrient inputs, may progressively deplete potassium in rice-growing soils (Zingore, Shamie, Wairegi, Lydia, and Ndiaye, Mamadou Kabirou, 2014). This reinforces the need for integrated soil fertility management combining mineral fertilisation (e.g., NPK) (Gueye *et al.*, 2019) with organic amendments such as well-decomposed compost, practices essential to restoring and maintaining fertility in irrigated rice systems.

Weed infestation is identified by farmers as one of the major production constraints in the study area, consistent with Rodenburg and Johnson(2009) and Diagne *et al.*(2013), who report weed pressure as a principal constraint to rice production in the Senegal River Valley. Its severity can be attributed to several interacting factors: the prolonged, repeated use of the same herbicide formulation (propanil combined with *Weedone*) over many years, and non-compliance with SAED's recommended application rates of 8 L propanil and 1 L *Weedone* per treatment (SAED *et al.*, 2011). The high quantities required for effective control also raise production costs, making chemical weed management economically inaccessible for many farmers. These constraints are further compounded by weak coordination among farmers on weed control and by the irrigation network configuration itself, where shared canals facilitate the spread of weeds between adjacent plots.

Bird damage represents another major constraint to rice production, primarily due to the seed-eating bird *Queleaquelea*, commonly known as the red-billed quelea, which occurs in large flocks across the southern Sahel. Because rice cultivation does not coincide with its preferred millet-based diet in certain seasons, the species shifts its feeding behavior toward rice fields, causing substantial yield losses along both banks of the Senegal River, losses De Mey, Demont and Diagne(2012) estimate at up to 13.2%. Potential mitigation strategies include bird-resistant rice varieties and strict adherence to recommended cropping calendars, which could help reduce fields' exposure during peak bird pressure.

The supplementary survey identified three cropping seasons within the year (HDS, CDS, and WS) consistent withHaefele, Wopereis and Donovan(2002) and Sakurai(2023), who describe the same seasonal pattern in the Senegal River Valley. Cultivating rice across two seasons is made possible by the relatively stable year-round water availability in the Senegal River, ensured by the Diama and Manantali dams, located downstream and upstream, respectively (SAED *et al.*, 2011). These hydraulic infrastructures have significantly improved water regulation, enabling intensified and continuous irrigation-based agriculture.
Rice remains the dominant crop in the study area, a predominance largely driven by national agricultural policies aimed at food self-sufficiency and reduced reliance on rice imports (Brosseau *et al.*, 2021). Other crops, particularly vegetables such as onion, are mainly grown within rotation systems primarily to generate cash income (Brosseau *et al.*, 2021; Diatta and Ndiaye, 2021; Sylla *et al.*, 2023). However, vegetable production is constrained by several factors, including high fertilizer costs, challenges in managing weeds, insect pests, and diseases, post-harvest losses from inadequate storage, and unfavourable market prices, constraints that collectively reduce profitability and lead most producers to prioritize rice over vegetables.
Water-depth practices point to suboptimal water management in the study area, consistent with Diaw *et al.*(2005), who reported unsustainable irrigation practices in the Senegal River Valley. The recommended water depth for fertilizer application (≤5 cm) and the required 72–96 hours interval before re-irrigation following herbicide application (SAED et al., 2011) are generally not respected by farmers, even though Kambou *et al.*(2014) found that maintaining a 5 cm depth reduces water losses and improves irrigation efficiency. These shortcomings stem from both biophysical and managerial factors. On one hand, poor land levelling, a consequence of poorly controlled irrigation scheme development (Diemer and Laan, 1987; Djaman *et al.*, 2017; Sakurai, 2023), leads to uneven water distribution across fields. On the other hand, many farmers intentionally maintain deeper water layers, generally 10–15 cm (Boivin, Pascal, Favre, Fabienne, and Maeght, Jean-Luc, 1998), believing this suppresses weed emergence (Zingore, Shamie, Wairegi, Lydia, and Ndiaye, Mamadou Kabirou, 2014). This practice deviates from recommended guidelines and may contribute to inefficient water use and reduced input effectiveness.

With an average cost of CFAF 100,000 ha^{-1}, irrigation accounts for roughly a quarter (25–29%) of total rice production costs in the middle Senegal River Valley (Krupnik *et al.*, 2012; Djaman *et al.*, 2017; Ibrahim *et al.*, 2021), consistent with JICA(2014), which reported irrigation costs of 98,400 CFA francs/ha in the dry season and 84,000 CFA francs/ha in the wet season, corresponding to diesel consumption of 164 L/ha and 140 L/ha, respectively. These figures underscore the significant economic burden of irrigation in the study area's rice systems, driven primarily by inefficient water management and the unsustainable irrigation practices documented by Diaw *et al.* (2005). Reliance on diesel-powered motor pumps (often fuel-inefficient and prone to frequent breakdowns) further raises operational costs and reduces system reliability, while poor coordination of water distribution and scheduling adds unnecessary energy consumption and water losses. Reducing irrigation costs would require better-coordinated distribution schedules at the scheme level alongside more efficient pumping technologies; fuel-efficient engines such as the ZS 1115 could meaningfully cut fuel consumption and operational expenses while improving reliability and overall efficiency.

The labor-intensive nature of manure application, combined with the large quantities required for meaningful agronomic effect, discourages its widespread use. As a result, despite the proximity of livestock systems and the availability of animal manure, organic soil amendments remain underused in rice cultivation, a limitation compounded by insufficient technical knowledge of composting and soil fertility management. Mineral fertilizers, particularly urea and diammonium phosphate (DAP 18-46-0), are used far more widely, a predominance driven largely by national policies aimed at intensifying rice production and achieving self-sufficiency. As part of this strategy, the government subsidizes these fertilizers at approximately 50% of cost (Seck, 2017), significantly boosting their accessibility and adoption among producers.

Conclusion

Rice farmers in the middle Senegal River Valley face multiple, interconnected constraints that limit production performance, most critically poor land levelling, weed infestation, bird damage from seed-eating species, high irrigation costs, and declining soil fertility linked to continuous cultivation and soil degradation. Together, these constraints reduce yields and increase production vulnerability.

The participatory co-construction approach adopted in this study enabled the identification of context-specific, potentially applicable solutions, including improved fertilisation management, strengthened extension and monitoring systems to ensure compliance with recommended input rates, and the adoption of more efficient motor pump technologies, such as engines based on the Chinese ZS 1115 model.

The analysis of production systems further revealed that irrigation schemes (GA, PIV, and PIP) are generally in poor condition, with outdated infrastructure, frequent pump failures, and inadequately designed canal networks lacking proper drainage, contributing significantly to inefficient water management and high production costs. Agricultural mechanisation also remains limited, particularly for land preparation, and farming is predominantly carried out by an ageing population, with most producers over 40 years old. Widespread reliance on mineral fertilisers, combined with limited knowledge of organic soil amendment practices, further underscores the system's technical constraints.

To ensure the effectiveness and relevance of the proposed solutions, field validation is necessary. A pilot trial has therefore been implemented within a farming community to assess the impact of selected interventions on rice yields and soil quality in village-based irrigation schemes. Results from this experiment are expected to inform future scaling strategies and support sustainable intensification of rice production in the region.

References

Bado, B.V., Aw, A. and Ndiaye, M. (2010) 'Long-term effect of continuous cropping of irrigated rice on soil and yield trends in the Sahel of West Africa', *Nutrient Cycling in Agroecosystems*, 88(1), pp. 133–141. Available at: https://doi.org/10.1007/s10705-010-9355-7.

Bado, V.B., Djaman, K. and Mel, V.C. (2018) 'Developing fertilizer recommendations for rice in Sub-Saharan Africa, achievements and opportunities', *Paddy and Water Environment*, 16(3), pp. 571–586. Available at: https://doi.org/10.1007/s10333-018-0649-8.

Balasubramanian, V. *et al.*(2007) 'Increasing Rice Production in Sub-Saharan Africa: Challenges and Opportunities', *Advances in Agronomy*. Elsevier, pp. 55–133. Available at: https://doi.org/10.1016/S0065-2113(06)94002-4.

Boivin, Pascal, Favre, Fabienne, and Maeght, Jean-Luc (1998) 'Les sols de la moyenne vallée du fleuve Sénégal : caractéristiques et évolution sous irrigation', *Étude et Gestion des Sols* [Preprint].

Brosseau, A. *et al.* (2021) 'Exploring opportunities for diversification of smallholders' rice-based farming systems in the Senegal River Valley', *Agricultural Systems*, 193, p. 103211. Available at: https://doi.org/10.1016/j.agsy.2021.103211.

Bruckmann, L. (2018) 'Crue et développement rural dans la vallée du Sénégal : entre marginalisation et résilience', *Belgeo* [Preprint], (2). Available at: https://doi.org/10.4000/belgeo.23158.

DAPSA (2020) *Rapport de la phase 1 de l'Enquête Agricole Annuelle (EAA) 2019-2020*, p. 102.

De Mey, Y., Demont, M. and Diagne, M. (2012) 'Estimating Bird Damage to Rice in Africa: Evidence from the Senegal River Valley', *Journal of Agricultural Economics*, 63(1), pp. 175–200. Available at: https://doi.org/10.1111/j.1477-9552.2011.00323.x.

Diagne, M. *et al.*(2013) 'Self-sufficiency policy and irrigated rice productivity in the Senegal River Valley', *Food Security*, 5(1), pp. 55–68. Available at: https://doi.org/10.1007/s12571-012-0229-5.

Diatta, J.-N.E. and Ndiaye, T.M. (2021) 'Diversification des cultures dans la vallée du fleuve Sénégal : impacts actuels sur l'autonomisation financière des petits producteurs de riz'.

Diaw, E.H.B. *et al.* (2005a) 'Étude expérimentale des transferts d'eau provoqués par l'irrigation sur une parcelle en moyenne vallée du fleuve Sénégal', *Revue des sciences de l'eau*, 15(4), pp. 721–736. Available at: https://doi.org/10.7202/705477ar.

Diaw, E.H.B. *et al.* (2005b) 'Étude expérimentale des transferts d'eau provoqués par l'irrigation sur une parcelle en moyenne vallée du fleuve Sénégal', *Revue des sciences de l'eau*, 15(4), pp. 721–736. Available at: https://doi.org/10.7202/705477ar.

Diemer, G. and Laan, E.C.W. van der (1987) *L'irrigation au Sahel: la crise des périmètres irrigués et la voie haalpulaar*. Wageningen, Pays-Bas : Paris, France: CTA ; Karthala.

Djaman, K. *et al.*(2017) 'Evapotranspiration, irrigation water requirement, and water productivity of rice (Oryza sativa L.) in the Sahelian environment', *Paddy and Water Environment*, 15(3), pp. 469–482. Available at: https://doi.org/10.1007/s10333-016-0564-9.

FAO (2021) *WORLD FOOD AND AGRICULTURE - STATISTICAL YEARBOOK 2021*. S.l.: FOOD & AGRICULTURE ORG.

FAO (2022) *WORLD FOOD AND AGRICULTURE STATISTICAL YEARBOOK 2022*. S.l.: FAO.

Gueye, H. *et al.* (2019) 'Effet de la fertilisation minérale sur la culture du riz (Oryza sativa L.) et du blé dur (Triticum durum Desf.) dans la vallée du fleuve Sénégal', *Journal of Animal & Plant Sciences*, pp. 6840–6846. Available at: https://doi.org/10.35759/JAnmPlSci.v41-1.10.

Haefele, S.M., Wopereis, M.C.S. and Donovan, C. (2002) 'FARMERS' PERCEPTIONS, PRACTICES AND PERFORMANCE IN A SAHELIAN IRRIGATED RICE SCHEME', *Experimental Agriculture*, 38(2), pp. 197–210. Available at: https://doi.org/10.1017/S001447970200025X.

Ibrahim, A. *et al.*(2021) 'Thirty years of agronomy research for development in irrigated rice-based cropping systems in the West African Sahel: Achievements and perspectives', *Field Crops Research*, 266, p. 108149. Available at: https://doi.org/10.1016/j.fcr.2021.108149.

JICA (2014) *Projet d'amélioration de la productivité du riz dans les aménagements hydro-agricoles de la vallée du fleuve Sénégal Rapport final (Rapport de syntèse)*, p. 48.

Kambou, D. *et al.* (2014) 'Concepts d'efficience et de productivité de l'eau (synthèse bibliographique)', *Biotechnology, Agronomy, Society and Environment*, 18(1).

Koutou, M. and Vall, E. (2010) 'IMPLICATION DES ACTEURS LOCAUX DANS LA CONCEPTION D'INNOVATIONS: LE CAS DES SYSTEMES AGROPASTORAUX DU TUY (BURKINA-FASO)', *Burkina Faso* [Preprint].

Krupnik, T.J. *et al.*(2012) 'Improving irrigated rice production in the Senegal River Valley through experiential learning and innovation', *Agricultural Systems*, 109, pp. 101–112. Available at: https://doi.org/10.1016/j.agsy.2012.01.008.

Mballo, R *et al.* (2018) 'Caractérisation de la flore adventice du riz irrigué dans quatre sites d'expérimentation dans la vallée du fleuve Sénégal', *Journal of Animal & Plant Sciences (J.Anim.Plant Sci. ISSN 2071-7024)* [Preprint].

Niang, A. *et al.* (2017) 'Variability and determinants of yields in rice production systems of West Africa', *Field Crops Research*, 207, pp. 1–12. Available at: https://doi.org/10.1016/j.fcr.2017.02.014.

Poussin, J.C. *et al.*(2003) 'Determinants of irrigated rice yield in the Senegal River valley', *European Journal of Agronomy*, 19(2), pp. 341–356. Available at: https://doi.org/10.1016/S1161-0301(02)00078-3.

Rodenburg, J. and Johnson, D.E. (2009) 'Weed Management in Rice-Based Cropping Systems in Africa', *Advances in Agronomy*. Elsevier, pp. 149–218. Available at: https://doi.org/10.1016/S0065-2113(09)03004-1.

SAED *et al.* (2011) *Manuel Pratique de Riziculture irriguée dans la Vallée du Fleuve Sénégal*.

Sakurai, T. (2023) 'Irrigation Scheme Size and Its Relationship to Investment Return: The Case of Senegal River Valley', in K. Otsuka, Y. Mano, and K. Takahashi (eds) *Rice Green Revolution in Sub-Saharan Africa*. Singapore: Springer Nature Singapore (Natural Resource Management and Policy), pp. 223–243. Available at: https://doi.org/10.1007/978-981-19-8046-6_11.

Seck, A. (2017) 'Fertiliser subsidy and agricultural productivity in Senegal', *The World Economy*, 40(9), pp. 1989–2006. Available at: https://doi.org/10.1111/twec.12487.

Sylla, E.H.M. *et al.* (2023) 'Is small beautiful ? L'irrigation dans le delta du fleuve Sénégal, une question de taille', *BASE*, pp. 96–108. Available at: https://doi.org/10.25518/1780-4507.20362.

Unger, P.W. *et al.* (1991) 'Crop residue management and tillage methods for conserving soil and water in semi-arid regions', *Soil and Tillage Research*, 20(2–4), pp. 219–240. Available at: https://doi.org/10.1016/0167-1987(91)90041-U.

USDA (2021) *Grain and Feed Annuel*, p. 13.

Vall, E. *et al.* (2016) 'La co-conception en partenariat de systèmes agricoles innovants', *Cahiers Agricultures*, 25(1), p. 15001. Available at: https://doi.org/10.1051/cagri/2016001.

Zingore, Shamie, Wairegi, Lydia, and Ndiaye, Mamadou Kabirou (2014) *Guide pour la gestion des systèmes de culture de riz*. (ASHC).