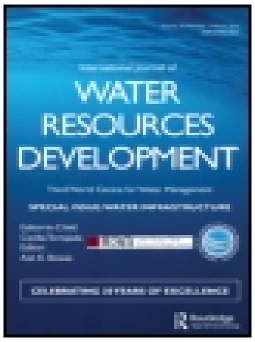

Routledge
Taylor & Francis Group

International Journal of Water Resources Development

ISSN: 0790-0627 (Print) 1360-0648 (Online) Journal homepage: http://www.tandfonline.com/loi/cijw20

Farmers' perceptions of irrigation and constraints on rice production in Benin: a stakeholder-consultation approach

Gbetondji Melaine Armel Nonvide, Daniel B. Sarpong, George T-M. Kwadzo, Henry Anim-Somuah & Fulbert Amoussouga Gero

INTERNATIONAL JOURNAL OF WATER RESOURCES DEVELOPMENT, 2017
https://doi.org/10.1080/07900627.2017.1317631

Farmers' perceptions of irrigation and constraints on rice production in Benin: a stakeholder-consultation approach

Gbetondji Melaine Armel Nonvide[a,b], Daniel B. Sarpong[a], George T-M. Kwadzo[a], Henry Anim-Somuah[a] and Fulbert Amoussouga Gero[b]

[a]Department of Agricultural Economics and Agribusiness, University of Ghana, Legon, Ghana; [b]Faculty of Economic and Management Sciences, University of Abomey-Calavi, Benin

ABSTRACT
This article examines rice farmers' perceptions of irrigation and constraints on rice production in the municipality of Malanville, Benin. Farmers' positive perceptions of irrigation include the use of irrigation for insurance against drought, crop yield improvement, higher income, food security and poverty reduction. Analysis of constraints reveals that farmers face major constraints such as lack of agricultural credit, poor access to production inputs, inadequate knowledge of water resources management, poor access to agricultural information and markets, and flooding of fields. Specific constraints in the irrigation scheme of Malanville include the high cost of irrigation and unavailability of water.

ARTICLE HISTORY
Received 18 May 2016
Accepted 31 March 2017

KEYWORDS
Irrigation; perception; constraints; rice; farmers; Benin

Introduction

Water management is an important challenge in developing countries; Benin is no exception. Without water, people do not have a means to produce crops and to provide food for the fast-growing population and for other animals, plants and microbes worldwide (Pimentel et al., 2004). Therefore, investing in water control tools such as irrigation is a key factor for agricultural development as it leads to productivity improvement (Domenech & Ringler, 2013; Huang, Rozelle, Lohmar, Huang, & Wang, 2006). In Benin, investments in irrigation started in 1960 with the technical and financial support of the Food and Agriculture Organization (FAO), West African Rice Development Association, World Bank, African Development Bank, Chinese technical partners and Taiwanese cooperation, among others. As a result the total irrigable land developed for crop production increased from 3932 ha in 1975 to 9724 ha in 1990 and 23,040 ha in 2008 (FAO, 2014). However, irrigation is still below its potential: less than 10% of the total irrigable land is currently developed, and the irrigation facilities are sub-optimally used (Table 1).

Rice occupies about 50% of the irrigated land; root and tuber, sugar-cane and vegetables occupy 21.1, 16 and 12.4%, respectively (FAO, 2014). This shows the priority that has been given to rice production in Benin. Rice is the main staple crop consumed by Beninese, after maize. Rice consumption has increased from 2.9 kg per capita per year in 1965 to 15 kg per

CONTACT Gbetondji Melaine Armel Nonvide gmanonvide@st.ug.edu.gh

Table 1. Uncropped land in formal irrigation schemes in Benin.

Irrigation scheme area	Land developed (ha)	Uncropped land	
		ha	%
Malanville	516	116.0	22.5
Koussin-lélé	120	8.2	6.8
Zonmon	88	51.9	58.9
Bamè	33	20.5	62.1
Benin (2008)	23,040	5,820	25.3

Source: Djagba et al. (2014), FAO (2014), Totin et al. (2012), Field survey (2015).

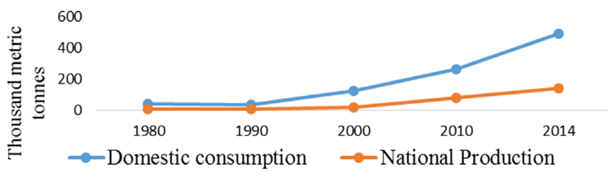

Figure 1. Aggregate consumption of rice and national production in Benin.

capita per year in 1994, and today 25–30 kg per capita per year (MAEP, 2010). Rapid population growth[1] and rising per capita consumption boosted domestic rice demand from 36,000 metric tonnes (t) in 1990 to 125,000 t in 2000, and 491,000 t in 2014 (Figure 1). Despite increases in national production, with annual growth of 8.2% since 1970, the excess demand for rice in Benin is still high and is often covered by imports. The imported rice covers on average 75% of rice consumption in Benin, an alarming dependency.

The aim of rice policy in Benin is to be self-sufficient in production by 2015, reaching 600,000 t of paddy by 2015 and export by 2018. To achieve this goal of self-sufficiency by 2015, the government introduced a number of key policies and investment strategies to increase domestic rice production. This is being done through a combination of adopting rice varieties better suited to local conditions, enabling access to good-quality inputs, supporting producers in the development of rice-growing areas, creating the necessary downstream post-harvest conditions to enhance the quality of local rice, and gaining a bigger share of the domestic market. However, domestic rice production was estimated at only 234,145 t of paddy in 2015 (MAEP, 2015), far below the target. To enhance rice production, it is vital to identify the key constraints being faced by rice farmers. Analysis of these constraints will help us better understand the real situation in the sector, identify good practices to overcome the barriers to enhancing rice production and sustainable development of the agricultural sector in Benin.

Considerable studies (Djagba et al., 2014; Nouatin, Kougbadi, & Afouda, 2009; Totin et al., 2012) have been conducted to analyze the constraints on rice production in Benin; however, not much attention has been given to involvement of farmers in the policy development process. Stakeholder engagement in policy development improves understanding of the problem and builds consensus to ensure the design of appropriate and implementable policies. Most studies of constraints on rice production (Djagba et al., 2014; Finckh, Naing, Kingsbury, & Buerkert, 2008; Igboji, Anozie, & Nneji, 2015; Singh, Singh, & Singh, 2013; Totin et al., 2012) have focused on one rice production system, though rice can be produced under several systems. For instance, in West Africa, rice is produced in rainfed uplands, rainfed lowlands, irrigated lands and mangrove swamps (Katic, Namara, Hope, Owusu, & Fujii, 2013). It is important to find out whether the constraints encountered are the same across different systems.

The present study adds to the literature on constraints on rice production in two different systems using a stakeholder-consultation approach. It aims to analyze farmers' perceptions about the use of irrigation for rice cultivation and the constraints faced by farmers in producing it. The specific objectives are to: (1) understand farmers' perceptions about the use of irrigation; (2) identify the constraints faced by farmers in rice production; and (3) propose suitable policy responses to overcome those constraints.

The remaining sections of the article are organized as follows. The next section provides a review of the literature. It is followed by a description of the study methodology, including the survey design, sample frame, data collection procedure, and method of data analysis. The results and discussion of the study are presented in the fourth section, and the final section is the conclusion and policy implications.

Literature review

There was increasing interest in support for irrigation from development organizations such as the World Bank, FAO and USAID as a result of major famines and food shortages in the 1950s and 1960s (Turral, Svendsen, & Faures, 2010). Lending for irrigation reached its peak between 1977 and 1979 and fell thereafter due to poor performance of the schemes, lack of maintenance, and decline in international food prices between 1980 and 1990 (Koohafkan, Salman, & Casarotto, 2012; Turral et al., 2010), but increased in recent decades because of the new challenges of climate variability and growing population and the international commitment to reduce food insecurity and poverty. For instance, the World Bank doubled its lending for irrigation in 2000–2010 (Mdee, Harrison, Mdee, Mdee, & Bahati, 2014; You et al., 2011). This interest in irrigation development support is based on evidence of the importance of irrigation development to support food production. Irrigation is an essential component of the modern package of inputs (improved seed, fertilizer, and improved tillage, among others) required to produce crop yields to meet the growing food demand (Carruthers, Rosegrant, & Seckler, 1997; Domènech, 2015; FAO, 2003). Beyond productivity improvement, irrigation interventions can also improve nutritional outcomes through availability of food supplies and improved diet, both in quantity and quality (Domenech & Ringler, 2013; Sinyolo, Mudhara, & Wale, 2014), and also contribute to poverty reduction (Adeoti, 2009; Dillon, 2011; Huang et al., 2006; Smith, 2004).

Despite the positive evidence for the importance of irrigation schemes, the successful development of such schemes is not without challenges, and many of them have largely failed, especially in Africa, due to high investment costs, declining cereal prices (Inocencio et al., 2007), poor planning and lack of maintenance (Kadigi, Tesfay, Bizoza, & Zinabou, 2012). Studies by Awulachew et al. (2005), Djagba et al. (2014), Ofosu, Van der Zaag, van de Giesen, and Odai (2014), and Shah, van Koppen, Merry, de Lange, and Samad (2002) identified six factors that contribute to the failure of irrigation schemes in Africa: high cost of irrigation development; lack of access to credit; lack of access to markets; ineffective institutions; lack of maintenance of irrigation infrastructure; and low productivity. Furthermore, irrigation scheme management style, irrigation method, crop mix, type of financing, and agro-ecological factors were reported by Mutiro and Lautze (2015) as factors handicapping irrigation development in Africa. They found that irrigation schemes with private-sector involvement perform better than those with government involvement; pump-based flood irrigation performs worse than flood irrigation without pumping, and sprinkler and drip irrigation; cereal-crop-based irrigation schemes perform poorly; schemes financed by development banks and the private sector perform better than those financed by governments, donors and aid agencies; and finally, irrigation schemes in humid and semi-arid zones perform better than those in other agro-ecological zones.

In Benin, the majority of the schemes developed between 1960 and 1980 were abandoned upon the withdrawal of foreign partners. Totin et al. (2012) investigated the technical and institutional factors that affect the effective use of irrigation water and the development of the local rice value chain in inland valleys in Benin. The three formal irrigation schemes covered by their analysis were the irrigation schemes of Koussin-Lélé, Bamè and Zonmon. Based on focus group discussions, the institutional barriers affecting the development of the local rice value chain include an unclear division of responsibilities between local farmer groups and the government for canal maintenance; a lack of effective local rules for the distribution and maintenance of irrigation infrastructure; and the constraining formal and informal credit systems and uncertain market outlets. Djagba et al. (2014) used focus group discussions and key informant interviews and concluded that granivorous birds and competition from weeds were by far the most important biophysical constraints in the inland valleys in Benin, followed by uncontrolled flooding and pests and diseases. In terms of socio-economic constraints, the farmers reported that they have no easy access to agro-chemical inputs for cropping, and that the inputs are too expensive. The work of Totin et al. (2012) and Djagba et al. (2014) focused on the same three formal irrigation schemes in inland valleys in Benin, and their results are complementary. However, these studies excluded the most important formal irrigation scheme in Benin (in terms of size, cropping season, and yield), the irrigation scheme of Malanville.

Alarima, Adamu, Masunaga, and Wakatsuki (2011) noted that water management and flooding were the most important on-farm constraints on the Sawah rice production system as perceived by a large percentage of farmers in Nigeria. The major economic constraints faced by Sawah farmers were lack of viable financial agencies to support production, poor capital base and nonavailability of loans. Similar results were found later by Igboji et al. (2015) in Ebonyi State, Nigeria. Using a factor analysis, they identified the major constraints limiting rice production as economic problems, infrastructural issues and unfavourable government policies. These included inadequate capital, high cost of transportation, high cost of labour, high cost of fertilizers and agro-chemicals, poor market outlet, inadequate supply of farm input, and poor storage facilities.

According to Finckh et al. (2008), the constraints on rice production in Myanmar are low rates of applied manure and chemical fertilizers, low seed quality, poor weed control, and water management. Thanh and Singh (2006) highlighted three major categories of constraints facing rice production in India and Vietnam: agro-ecological, technical and socio-economic. These appear to be the most limiting constraints on rice production in India and Vietnam. The agro-ecological constraints include dependence on the monsoon, land and soil problems, environmental pollution, lack of water, and small land holdings. The technical constraints that were found are diseases, pests, lack of proper varieties, post-harvest technology constraints and storage problems. The socio-economic constraints include poor infrastructure, high cost of inputs, credit problems, low paddy price, inadequate inputs and lack of training. Thanh and Singh (2006) compared the production constraints between two different systems of production: irrigated and rainfed farming. Despite the difference in production systems, the constraints faced by Indian and Vietnamese farmers were similar. Thanh and Singh (2006) argue that this might be because both countries are developing countries. Constraints in intercropping systems also have been analyzed in India. In a rice-wheat cropping system, Singh et al. (2013) found that the major constraints responsible for yield gap were late sowing or transplanting, higher prices of high-yield-variety seed, nonavailability of fertilizer at sowing time, lack of financial support for farmers, and infestation of pests and disease.

John and Fielding (2014) analyzed results in journal articles published between 1997 and 15 February 2014 that had focused on rice production constraints in South Asian farming systems. They found that research was focused on socio-economic, abiotic, biotic and management-related constraints on rice farming. The major socio-economic constraints were unavailability of high-quality seed and high cost of irrigation. The abiotic constraints included drought or intermittent water stress, soil fertility depletion and nitrogen deficiency, while the biotic constraints were weed competition, leaf and stem pests, and leaf, stem and panicle diseases. The most severe management-related constraints were inadequate water management, inappropriate and poor nutrient and fertilizer use, late planting of crops, and use of low-yield or old varieties of rice. John and Fielding (2014) noted that while research has focused on several of the most severe production constraints, many constraints have not received the much-needed attention from research. For instance, few studies have focused on socio-economic constraints, despite their being the most important category of production constraints.

Materials and methods

Study area and survey design

This study was conducted in the municipality of Malanville, in Benin (Figure 2). The details of the survey can also be found in a conference paper (Nonvide, 2016) which used the same database. The municipality of Malanville shares its boundaries with the Republic of Niger to the north, the municipalities of Kandi and Ségbana to the south, the municipality of Karimama to the west, and the Federal Republic of Nigeria to the east. It covers 3016 km^2, of which 8000 ha is arable land.

The municipality is in the Sudano-Sahelian zone of Benin, which is characterized by one dry season and one rainy season. Rains begin in May and end in October, with annual rainfall between 700 and 1000 mm. This low rainfall hinders agricultural production, especially rice, maize and vegetables. Malanville has high food insecurity and poverty (Table 2). Crop production, and other economic activities including livestock rearing, fishing, small business, trade and crafts, are the main livelihood strategies for the majority of the population. Farmers in the municipality produce mainly maize, rice, millet, sorghum, cotton and vegetables.

The municipality of Malanville was selected for this study due to its importance to rice production in Benin. It is the largest rice-producing zone in Benin. It is in the Niger River basin, which offers an important opportunity for rice production, and among the rice irrigation schemes developed by the state, the one in Malanville is the most important in terms of size, cropping season, and yield. The irrigation scheme of Malanville covers 516 ha, of which 400 ha were used for two seasons in 2015. The average rice yield is about 5.7 Mt/ha. The scheme was constructed in 1970, and the water used is pumped from the Niger River and distributed through surface canals into 1054 rice farms, as of 2015 (Nonvide, 2016).

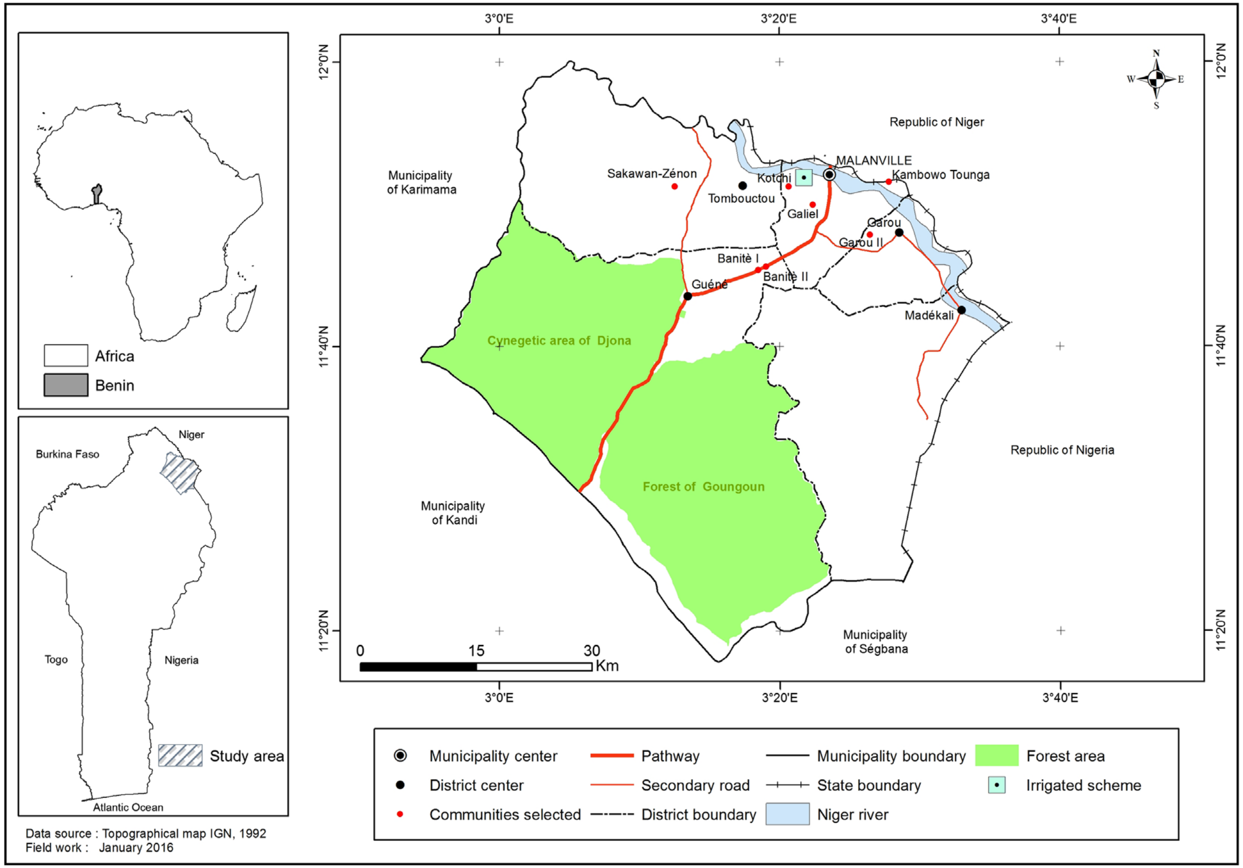

Figure 2. Location of the study sites.

Table 2. Socio-economic characteristics of the municipality of Malanville, Benin.

Population (2013)	168, 641
Religion	Muslim, 80%; others, 20%
Child schooling (%)	28.4
Literacy (%)	14.1
Main economic activities	Agriculture, fishing, livestock, small business, trade and crafts
Major crops	Maize, rice, millet, sorghum, cotton, vegetables
Food insecurity (%)	35
Poverty (%)	42.5

Source: Institut National de la Statistique et de l'Analyse Economique (2011, 2013).

Table 3. Size of rice production among districts in 2013–2014 cropping year.

Districts	Production (t)
Malanville	15,594
Garou	9,139
Guene	6,238
Madecali	4,456
Tombouctou	7,128
Total for the municipality	42,555

Source: Centre d'Action Régionale pour le Développement Rural (CARDER- Malanville), 2015.

Four districts out of five were selected for the survey. District selection was based on the distance to the irrigation scheme and on the size of rice production. The districts selected were Garou, Guene, Malanville and Tombouctou (Table 3).

Two villages, one high-rice-producing and one low-rice-producing, were purposively selected within each of these districts with the help of the extension officers. In total, eight villages in the four districts were selected for the survey.

Respondent sampling design and data collection

Stratified random sampling was used to select the survey respondents. The reason for stratification is that differences exist in the production system among rice farmers. They were classified into two strata: irrigation farmers and dry-land farmers. The irrigation farmers produce rice under irrigation in the formal irrigation scheme of Malanville, and the dry-land farmers produce rice under rainfed conditions in the same municipality. MAEP (2015) reports that about 9% of the rice-farmer population in Benin are irrigation farmers, while the rest are dry-land farmers. Based on this distribution of irrigation and dry-land farmers, the sample size required for the sample to be statistically representative of the population was determined for each group of farmers using Cochran's (1977) formula:

$$n = z^2 \times p(1 - p)/m^2$$

where n is the required sample size; z is the confidence level at 95% (standard value is 1.96); p is the estimated prevalence of rice farm attribute (proportion of rice farmers using irrigation and dry land); and m is the margin of error at 5%. For irrigation farmers, using this formula, we obtained a sample size of 126; for dry-land farmers the optimal sample size was estimated at 359. For oversampling, 150 irrigation farmers and 540 dry-land farmers were finally chosen. A large sample size reduces sampling error and gives better statistical reliability for estimates.

Table 4. Number of respondents interviewed per community.

District	Villages/communities	Production systems	Population	Sample size
Malanville	• Irrigation scheme	Irrigated	1,054	150
	• Kotchi[a]	Rainfed	427	90
	• Galiel[b]	Rainfed	108	45
Garou	• Garou II[a]	Rainfed	673	90
	• Kambowo tounga[b]	Rainfed	178	45
Guene	• Banité II[a]	Rainfed	268	90
	• Banité I[b]	Rainfed	91	45
Tombouctou	• Tombouctou[a]	Rainfed	614	90
	• Sakwan Zenon[b]	Rainfed	112	45
Total			3,525	690

Note: [a]high rice growing area; [b]low rice growing area.
Source: Centre d'Action Régionale pour le Développement Rural (CARDER- Malanville), 2015

In practice, the list of irrigation farmers was provided by the committee in charge of the management of the irrigation scheme of Malanville (Nonvide, 2016). Irrigation farmers are located in the scheme in groups of 20 to 100 people, with a total of 1054 rice farmers operating in the scheme in 2015. From these groups, proportional sampling was used to obtain 150 irrigation farmers such that at least 3 and at most 15 were selected from every group. A random sample of dry-land farmers was also obtained. For this group, the list of rice farmers was gotten from the chief of the village. This was the sampling frame from which the dry-land farmers were selected. Ninety farmers were randomly selected in each high-rice-producing village, and 45 in each low-rice-producing village (Table 4). Hence, 540 dry-land farmers were selected. In all, 690 rice producers, including 150 irrigators and 540 dry-land farmers, were interviewed for the survey.

Questionnaires were pre-tested in the municipality of Malanville with both irrigation and dry-land farmers and modified accordingly before being administered. For the irrigation farmers, the majority of the interviews were conducted in the scheme, as it was easy to meet farmers there, while for the dry-land farmers most of the interviews were conducted at the respondent's home. To increase data validity and reliability, enumerators fluent in the local language (Dendi) were selected and trained to administer the interviews. The training included an overview of the research project and the rationale underlying the questions. To ensure consistency, a second meeting was held with each enumerator once they had completed five interviews. The survey was conducted between April and June of 2015.

Methods of analysis

A stakeholder-consultation approach was used in the study. This approach involves the rice farmers in each stage of the analysis. They expressed their perceptions of irrigation and the constraints encountered in rice farming. They were also asked about solutions to overcome these constraints.

Table 5. Predefined statements on perception of irrigation.

	Statement	Adapted from
A	Using irrigation may lead to crop yield improvement	Carruthers et al. (1997), Huang et al. (2006), Domenech and Ringler (2013)
B	Irrigation development creates employment opportunity	Hussain and Hanjra (2004), Lipton et al. (2003)
C	The use of irrigation is an insurance against drought	Hanjra et al. (2009), Lipton et al. (2003)
D	Irrigation ensures high net income	Chazovachii (2012), Gebregziabher et al. (2009), Lipton et al. (2003)
E	Irrigation may contribute to achieve food security in my community	Domènech (2015), Mangisoni (2008), Sinyolo et al. (2014), Tekana and Oladele (2011)
F	Irrigation may lead to poverty reduction	Dillon (2011), Huang et al. (2006), Hussain and Hanjra (2004), Smith (2004)
G	Irrigation increases the cost of production	FAO (2003), Koundouri, Nauges, and Tzouvelekas (2006)
H	Irrigation maximizes the return on other inputs such as fertilizer, labour, etc.	Hussain and Hanjra (2004), Lipton et al. (2003), Smith (2004)
I	The development of irrigation contributes to reducing out-migration	Domènech (2015), Hussain and Hanjra (2004)
J	Irrigation water has multiple uses, including agriculture, domestic, and livestock uses	Domènech (2015), Meinzen-Dick and Van der Hoek (2001)

Analytical framework of farmers' perceptions of irrigation

The perceptions of farmers were obtained from individual rice farmers in each community selected. Farmers expressed their perceptions on irrigation on the predefined statement identified from the literature about the various socio-economic effects of irrigation (Table 5). A five-point Likert scale was used (strongly agree; agree; neutral; disagree; strongly disagree). The results were analyzed using frequencies and percentages. The predefined statement with the highest percentage was taken to represent the most prevalent perception on irrigation. Then each predefined statement was ranked on the basis of its percentage score and comparison was made between irrigators and dry-land farmers.

Analytical framework for the constraints on rice production

The constraints analysis followed two procedures. First, a set of constraints (Table 6) encountered in rainfed and irrigated rice farming was identified from the literature, and farmers

Table 6. Set of constraints on rice production.

	Constraint	Adapted from
A	Irrigation water is not available all the time	John and Fielding (2014), Singh et al. (2013), Thanh and Singh (2006)
B	Lack of agricultural credit	Alarima et al. (2011), Schut et al. (2015), Totin et al. (2012)
C	Inadequate farmers' knowledge of water resources management	Amede (2015), Finckh et al. (2008), Ogunjimi and Adekalu (2002)
D	Unavailability of high-quality seed	Finckh et al. (2008), Singh et al. (2013), Thanh and Singh (2006)
E	High cost of using irrigation water	John and Fielding (2014), Waddington et al. (2010)
F	Unavailability of labour	Igboji et al. (2015), Mghase et al. (2010), Singh et al. (2013)
G	Poor access to fertilizer and agro-chemicals	Djagba et al. (2014), Igboji et al. (2015), Singh et al. (2013), Totin et al. (2012)
H	Flooding of fields	Diagne et al. (2013), Finckh et al. (2008)
I	Poor access to agricultural information	John and Fielding (2014), Thanh and Singh (2006)
J	Poor access to market	Igboji et al. (2015), Totin et al. (2012)

Table 7. Profile of the survey respondents.

Variable	Categories	Irrigation farmers (%)	Dry-land farmers (%)	t-test/χ^2
Age	20–35	39.33	22.59	2.15**
	36–65	56.00	75.74	
	66–74	4.67	1.67	
Gender	Male	80.67	72.41	4.18**
	Female	19.33	27.59	
Religion	Christian	14.66	01.30	56.02***
	Muslim	84.00	98.14	
	Traditional	0.67	0.56	
	Atheist	0.67	0	
Marital status	Single	14.67	5.56	17.34***
	Married	80.67	92.22	
	Divorced	2.00	1.11	
	Widowed	2.67	1.11	
Education	None	66.67	63.89	0.39
	Primary	22	23.89	
	Secondary	11.33	12.22	
Farm size (ha)	≤0.5	66	19.44	11.04***
	0.5–2	34	62.97	
	>2	0	17.59	
Labour source	Hired	6.67	13.70	86.19***
	Family	15.33	50.74	
	Both	78	35.56	
Use of improved seed	Yes	100	44.07	149.18***
	No	0	55.93	
Use of fertilizer	Yes	99.33	98.89	0.23
	No	0.67	1.11	
Fertilizer application rate (kg/ha)		305.33	226.20	−10.38***
Extension visits	Yes	94	48.89	98.53***
	No	6	51.11	
Membership in rice farmers association	Yes	98.67	31	219.72***
	No	1.33	69	
Engaged in off-farm activities	Yes	58	26.5	52.47***
	No	42	73.5	

**$p < .05$; ***$p < .01$.

were asked to give their perceptions using the five-point Likert scale. Second, if the farmers rated the constraint 'strongly agree' or 'agree', then they agreed that it was a serious constraint and hence were asked about its causes and solutions. Farmers were also asked to report other constraints they are facing. The results were analyzed using frequencies and percentages. The constraint which had a highest score was ranked priority 1. Comparison was made to see whether the constraint priority depended on the rice production system.

Results and discussion

Profile of the survey respondents

Summary statistics of the respondents are presented in Table 7. There are significant differences in the socio-economic and demographic characteristics between the irrigation and dry-land farmers. Some 81% of the irrigators and 72% of the dry-land farmers are male. The significantly lower proportion of female producers is consistent with the findings of Alarima et al. (2011). The average age of the irrigators was 40, against 42 for dry-land farmers. A significantly higher proportion of irrigators are between 20 and 35, suggesting that it is the younger farmers who engage in irrigated farming. The majority (95%) of the surveyed farmers were Muslims. Concerning marital status, the majority of irrigators (81%) and dry-land farmers (92%) were married. This suggests that married people have more responsibilities, like feeding their families (Igboji et al., 2015). No significant difference in education was seen between irrigators and dry-land farmers. About 67% of irrigators and 64% of dry-land farmers had no formal education; 33% and 36% of irrigation and dry-land farmers, respectively, had at least primary school. The average irrigated farm size was 0.5 ha, while for rainfed farming this was 1.5 ha. The majority of the rice farmers used fertilizer for rice production; no significant difference was noted between irrigation and dry-land farmers. However, there was a significant difference in the rate of fertilizer application. The irrigation farmers applied an average of 305 kg of fertilizer per hectare, whereas the dry-land farmers applied on average of 226 kg per hectare. Fertilizer application rates were significantly higher in irrigated than in rainfed farming. The application rate of dry-land farmers is below the recommended rate of 300 kg/ha in the municipality of Malanville. Irrigation farmers are significantly more likely to access support services and thereby benefit from institutional support. For instance, all the irrigators used improved rice seed, against only 44% of dry-land farmers. Almost all (94%) irrigation farmers had received extension visits in the last year, while only 49% of dry-land farmers had. Almost 100% of the surveyed irrigation farmers but only 31% of the dry-land farmers belonged to a rice farmers association. The significant difference in the institutional variable may be due to the importance that has been given to the development of irrigation in Benin. With regard to off-farm work a significant difference was also observed, with 58% of irrigation farmers and 27% of dry-land farmers participating in such activities. Respondents worked mainly in petty trade (30.4%), fishing (11.9%), charcoal or firewood selling (10.6%), livestock (7.9%) and as farm hands (7.9%).

Farmers' perceptions of irrigation

For the purposes of this article, the ratings 'strongly agree' and 'agree' were combined and labelled 'agree'. Similarly, 'strongly disagree' and 'disagree' were combined and labelled 'disagree'. At least 75% of the irrigation farmers perceived that irrigation plays the following important roles in agricultural development and economic growth (Table 8): productivity improvement (80%), employment opportunity (79%), insurance against drought (82%), high

Table 8. Percentage of rice farmers in agreement on the importance of irrigation.

Statements	Irrigation farmers (%)	Dry-land farmers (%)	χ^2
Using irrigation may lead to crop yield improvement	80	74.45	34.86***
Irrigation development creates employment opportunity	78.66	64.26	53.94***
The use of irrigation is an insurance against drought	82	77.78	24.79***
Irrigation ensures high net income	91.94	66.86	44.05***
Irrigation may contribute to achieve food security in my community	92.67	71.67	43.79***
Irrigation may lead to poverty reduction	88.67	59.51	70.79***
Irrigation increases the cost of production	85.33	60.37	52.51***
Irrigation maximizes the return on other inputs such as fertilizer, labour, etc.	65.34	57.59	47.92***
The development of irrigation contributes to reducing out-migration	51.33	54.63	50.04***
Irrigation water has multiple uses, including agriculture, domestic, and livestock uses	48.67	61.29	19.5***

***$p < .01$.

net income (92%), contribution to food security (93%), and poverty reduction (89%). However, 85% of the irrigators indicated that irrigation increases the cost of production. This is due to the high cost of water and other services provided in the formal irrigation scheme of Malanville. For instance, the irrigation farmers paid 12 bags of paddy (bags are 84 kg each) as water fees per hectare. This represents about 18% of the total rice output, as the average irrigated rice yield is 5.7 t/ha, for an average of 68 bags of paddy. About 65% of the irrigation farmers recognized that irrigation maximizes the return on other inputs, such as fertilizer and labour, while 51% of the farmers agreed that irrigation contributes to reducing out-migration. Less than 50% of the irrigation farmers agreed that irrigation water has multiple uses, including agriculture, domestic and livestock uses. This represents the lowest level of agreement with any of the perception variables tested. In fact, only those farmers living nearest to the irrigation scheme could use the water for other purposes.

Table 8 also shows that at least 60% of dry-land farmers perceived that irrigation may lead to development through crop yield improvement (74%), creation of employment opportunity (64%), insurance against drought (78%), increasing income (67%), food security (72%), and poverty reduction (60%). However, 60% of the dry-land farmers agreed that the use of irrigation may increase the cost of production due to additional costs, including water charges. Beyond agriculture, irrigation water has multiple uses, including domestic and livestock uses. This view was agreed by 61% of dry-land farmers. Approximately 58% agreed that irrigation maximizes the return on other inputs, such as fertilizer and labour. Finally, 55% of the farmers perceived that the development of irrigation contributes to reducing out-migration.

The three most prevalent perceptions on irrigation from irrigators were: irrigation may contribute to food security (93%); irrigation ensures high net income (92%); and irrigation may reduce poverty (89%). From the dry-land farmers' point of view, these were: the use of irrigation is an insurance against drought (78%); using irrigation may improve crop yields (74%); and irrigation may contribute to food security (72%).

In general, the two groups of farmers perceived irrigation favourably. However, a larger proportion of irrigators agreed with the statements. This may be explained by differences in access to agricultural information. Indeed, agricultural information can be shared through extension services, media, and farmer-based organizations. The percentage of irrigators that reported receiving extension visits in the past year, having access to agronomic practices through the media, and belonging to rice farmers associations was significantly higher (Table 9). Inaccessibility of agricultural information thus affects farmers' perceptions of irrigation.

Also, one group is already using the irrigation system, while the second group is not. The dry-land farmers expressed expectation of using irrigation. They perceived irrigation as insurance against drought and a means for crop productivity improvement. The irrigation farmers' perception was guided by their experiences in using irrigation. They highlighted the

Table 9. Extension visits, access to media, and belonging to rice farmers associations.

	Irrigation farmers (%)	Dry-land farmers (%)
Extension services	94	48.89
Media	26.67	15.37
Rice farmers organization	98.67	31

Source: Field survey (2015).

Table 10. Factors explaining the low use of irrigation facilities in Benin.

Reasons	Frequency	Percentage
Financial constraints	343	63.5
Institutional constraints	46	8.5
Irrigation is not beneficial	162	30

Source: Field survey (2015).

contribution of irrigation to food security and higher income. This goes beyond the immediate outcomes of irrigation as perceived by the dry-land farmers.

Although more than 50% of the farmers interviewed perceived irrigation favourably, the irrigation facilities are sub-optimally used. Table 10 presents farmers' reasons for the low use of irrigation facilities. Although participation in the formal irrigation project was accompanied by other benefits, such as access to credit, provision of fertilizers and agro-chemicals, and marketing of paddy rice, financial constraints was by far the most important reason. The majority (64%) of the dry-land farmers reported that they could not afford the high cost of irrigation. Even irrigators cited the high cost as a major constraint. In addition to farmers stating the high cost of using irrigation, other factors could explain the financial constraints. For instance, the majority of the farmers sell their rice at the farm gate or at their homes rather than sending it to the market. While selling rice at the farm gate reduces transaction costs, it is often less remunerative, as sellers may have limited choice of buyers and lack information on real prices. The most important rice buyers in the municipality of Malanville are the state, followed by rice exporters. Of the farmers sampled, 79% declared that they sold their rice to the state, while 27% sold to exporters from neighbouring countries like Nigeria, Niger and Togo. Rice prices are determined by the state, as the farmers have no bargaining power or access to nearby alternative markets. In fact, the price set by the state is often lower than those offered in urban markets and in the neighbouring countries. For instance, in 2015 the state paid CFA 170/kg for paddy rice, while it was CFA 200 in the urban markets and CFA 220 in the neighbouring countries. Farmers who have access to these alternative markets get better prices and have higher returns, despite higher transaction costs. Also, as farmers are often in need of cash, they sell the majority of their rice immediately after harvesting, when prices are lowest. Rice processing is another problem. Only 3% of the surveyed rice farmers process their paddy rice and sell the milled rice; the vast majority (96%) sell their rice in the form of paddy, without adding value through processing. These factors may affect the overall returns from the sale of rice due to low prices.

Constraints on rice production

Major constraining factors reported by more than 50% of the dry-land farmers (Figure 3) include lack of agricultural credit (83%), followed by unavailability of high-quality seed (73%), inadequate knowledge of water resources management (72%), poor access to agricultural information (71%), poor access to market (69%), flooding of fields (68%), poor access to fertilizer and agro-chemicals (62%), and unavailability of labour (52%). These constraints are also experienced by approximately 30% of irrigation farmers. Other constraints reported by the dry-land farmers are land degradation (9%), lack of agricultural machines (7%), crop failure (5%) and storage problems (5%). Specific constraints on irrigated farming are the high cost of using irrigation (60%), flooding of fields (59%), and unavailability of irrigation water

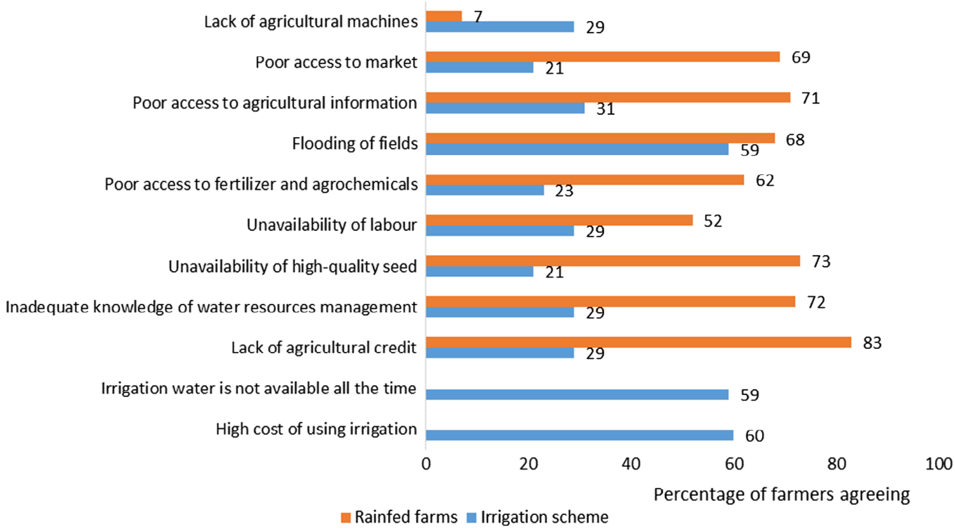

Figure 3. Major constraints on rice production as perceived by farmers.

all the time (59%). The latter two are technical problems caused by the poor drainage system and frequent breakdown of pumps, respectively. Discussions with the irrigation leaders suggest that another reason for the lack of adequate water supply is the high cost of fuel for pumps. Diesel was used beginning in 1970. Due to the high cost, the pumps were linked to the electricity company in 2008. But this did not solve the problem because the electricity supply is unreliable. A sustainable alternative would be the use of solar pumps, which are suited to the climate of the area, with its high temperatures (average of 32 °C).

The results of this study are in line with those found in the literature on the constraints on farming in general and especially rice farming (Alarima et al., 2011; Djagba et al., 2014; Finckh et al., 2008; Igboji et al., 2015; John & Fielding, 2014; Mdemu, Mziray, Bjornlund, & Kashaigili, 2016; Singh et al., 2013; Thanh & Singh, 2006; Totin et al., 2012). Although the rice farmers face similar constraints to those mentioned above, it is important to notice that they are not equally affected. Important differences are observed between them (Tables A1 and A2, in the appendix). The dry-land farmers benefit less from institutional support (credit, extension services, and market). This can be seen in Table 7. Indeed, the development of an irrigation scheme is often a package of technology including, in addition to water security, accessibility to other inputs such as improved seed, fertilizer and agro-chemicals, and other services such as extension services and access to credit and markets. Another clear difference was observed in access to agricultural information. Irrigation farmers have more access. In addition to extension services (Table 9), farmers use a number of sources, including media and farmer-based organizations, to access information. These observed differences are likely to be important causes of the low productivity among the dry-land farmers. So a good policy would pay more attention to the dry-land farmers, in order to close the gaps between them and the irrigation farmers. This might help boost rainfed rice productivity. For example, regular contact with extension agents might help farmers with information on new technologies, availability of farm inputs, and markets for their output. Accessibility of finance would enable farmers to secure farm inputs in time, as well as to buy farm equipment, and

Table 11. Reasons for inaccessibility of credit.

Reasons	Percentage of farmers
Lack of collateral	31.58
High interest rate	13.43
Lack of guarantor	24.65
Credit rationing	26.39
Don't know	8.37

Source: Field survey (2015).

protect them from having to sell their output at a low price. In this regard, the findings of this article suggest that lack of credit might be the core cause of many of the constraints faced by rice farmers. This is supported by Mdemu et al. (2016), who found that lack of credit prevents farmers from securing high-quality seed, appropriate fertilizer and agro-chemicals, and storage facilities for their output. The survey found that the main reason for limited access to credit is lack of collateral, followed by credit rationing and lack of a guarantor (Table 11). Collateral and guarantors are required to obtain credit from the financial institutions. This limits credit accessibility for farmers because most of them are unable to provide a property title to serve as a collateral (Mdemu et al., 2016; Piza & de Moura, 2016). Informal discussions with credit agents at financial institutions suggest that the amount of credit accorded often depends on farm size. This justifies the fact that some farmers (38%) do not receive the full amount requested, although they have satisfied the requirements.

To address the financial needs of the farmers and increase rice production in Benin, farmers proposed (Tables A1 and A2, in the appendix) subsidy of productive inputs (water, fertilizers, agro-chemicals, etc.). Indeed, during the 1960s and 1970s, subsidized rural credit was seen as an answer to low productivity and poverty in developing countries (Braverman & Guasch, 1986; Dorward & Chirwa, 2011). Now, it is widely recognized that subsidized credit exacerbates income inequality. Well-off farmers benefit more from such subsidies than the poor and vulnerable farmers targeted (Amin, Rai, & Topa, 2003; Kamwamba-Mtethiwa, Namara, De Fraiture, Mangisoni, & Owusu, 2012). In sum, subsidy programmes are criticized for not reaching the target group, for being subject to misuse and corruption in the process of distribution, and for imposing government budget burdens. In Malawi, an evaluation of the treadle pump price subsidy programme developed in 1999 indicated that relatively well-off farmers had a significantly higher probability of adopting treadle pumps than poor farmers (Kamwamba-Mtethiwa et al., 2012). According to the programme evaluation team, the subsidy was seen as free of charge and therefore reduced the sustainability of the treadle pump technology. It would be necessary to educate farmers on the right usage of loan facilities rather than to provide them subsidized loans, as access to credit is vital for agricultural development. In this regard, there is a need for a clear policy framework on farm credit management.

Conclusion and recommendations

Developing the rice sector has been a top priority of agricultural policy in Benin since 1960. In that regard, several irrigation schemes have been developed to support rice production in the country. The objective of this study is to analyze farmers' perceptions of irrigation and constraints on rice production in Benin. It also indicates suitable solutions as proposed by the farmers to overcome those constraints. The two rice production systems considered for the analysis were irrigated and rainfed. A total of 690 rice farmers were interviewed. A stakeholder-consultation approach was used during the survey. This implies an involvement of farmers in the policy-response process. Farmers expressed their perceptions of irrigation and the constraints on rice production. They were also asked about causes and solutions. The most prevalent perceptions of irrigation from irrigators included contributions to food security, income, and poverty reduction. From dry-land farmers, these were irrigation as insurance against drought, improvement of crop yield, and food security. The major constraining factors in the rice sector are lack of agricultural credit, unavailability of high-quality seed, inadequate farmers' knowledge of water resources management, poor access to agricultural information, poor access to market, flooding of fields, poor access to fertilizer and agro-chemicals, lack of agricultural machines, and unavailability of labour. Specific constraints on the irrigation scheme of Malanville include the high cost of irrigation and unavailability of irrigation water. Other constraints perceived by the dry-land farmers include land degradation, crop failure and storage problems.

Possible solutions to the constraints were also indicated by the farmers. These imply the following policy recommendations to improve rice production in Benin. Because there are important differences among rice farmers in terms of institutional support services (extension services, improved seed, credit, and market), there is a need to narrow the gaps by improving institutional support for dry-land farmers. In general, there is a need to provide credit facilities for the farmers. They should also be educated on the right usage of loan facilities rather than to provide them subsidized loans. It is urgent to develop agricultural mechanization policy, which may include an agricultural inputs supply programme. There is also a need to improve the mechanism of rice information sharing, based on improvement of extension services and the development of rice production programmes in the media (radio, television, etc.). Farmers' skills in water management should be improved through regular training on water resources management. The training should use participatory approaches. Another key policy issue is the development of market outlets for rice. Farmers mostly sell their rice either at the farm gate or at their home. The state, through its company (SONAPRA), is the major buyer of rice. The state buys the rice from the farmers on credit. As most of the farmers are in need of cash, that situation does not incent them. Also, in years when the state delays buying rice, the situation becomes critical for the farmers. Farmers need information on rice prices, markets for rice, and input prices. Regarding the irrigation scheme of Malanville, there is a need for regular repair, maintenance and rehabilitation of the irrigation facilities. The flooding problem should be resolved through improvement of the drainage system, as this is the main cause of flooding in the irrigation scheme.

Note

1. The fourth census, in 2013, indicated that Benin's population had increased at 3.5% between 2002 and 2013, against 3.2% between 1992 and 2002 (INSAE, 2013).

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Adeoti, I. A. (2009). Factors influencing irrigation technology adoption and its impact on household poverty in Ghana. *Journal of Agriculture and Rural Development in the Tropics and Subtropics, 109*, 51–63.

Alarima, C. I., Adamu, C. O., Masunaga, T., & Wakatsuki, T. (2011). Constraints to Sawah rice production system in Nigeria. *Journal of Human Ecology, 36*, 121–130.

Amede, T. (2015). Technical and institutional attributes constraining the performance of smallscale irrigation in Ethiopia. *Water Resources and Rural Development*, *6*, 78–91. doi:10.1016/j.wrr.2014.10.005

Amin, S., Rai, A. S., & Topa, G. (2003). Does microcredit reach the poor and vulnerable? Evidence from northern Bangladesh. *Journal of Development Economics, 70*, 59–82.

Awulachew, S. B., Merrey, D. J., Kamara, A. B., Van Koppen, B., Penning de Vries, F., Boelee, E., & Makombe, G. (2005). *Experiences and opportunities for promoting small-scale irrigation and rainwater harvesting for food security in Ethiopia*. Colombo: International Water Management Institute, (Working Paper) Sri Lanka, 98.

Braverman, A., & Guasch, J. L. (1986). Rural credit markets and institutions in developing countries: Lessons for policy analysis from practice and modern theory. *World Development, 14*, 1253–1267.

Carruthers, I., Rosegrant, M. W., & Seckler, D. (1997). Irrigation and food security in the 21st century. *Irrigation and Drainage Systems, 11*, 83–101.

Chazovachii, B. (2012). The impact of small scale irrigation schemes on rural livelihoods: The case of panganai irrigation scheme Bikita District Zimbabwe. *Journal of Sustainable Development in Africa, 14*, 217–231.

Cochran, W. G. (1977). *Sampling techniques* (3rd ed.). New York, NY: Wiley.

Diagne, A., Alia, D. Y., Amovin-Assagba, E., Wopereis, M. C. S., Saito, K., & Nakelse, T. (2013). Farmer perceptions of the biophysical constraints to rice production in Sub-Saharan Africa, and potential impact of research. In M. C. S. Wopereis, D. E. Johnson, N. Ahmadi, E. Tollens, & A. Jalloh (Eds.), *Realizing Africa's rice promise* (pp. 46–68). Wallingford, Oxfordshire, UK: CAB International.

Dillon, A. (2011). The effect of irrigation on poverty reduction, asset accumulation, and informal insurance: Evidence from Northern Mali. *World Development, 39*, 2165–2175.

Djagba, J. F., Rodenburg, J., Zwart, S. J., Houndagba, C. J., & Kiepe, P. (2014). Failure and success factors of irrigation system developments: A case study from the Ouémé and Zou valleys In Benin. *Irrigation and Drainage, 63*, 328–339.

Domènech, L. (2015). Improving irrigation access to combat food insecurity and undernutrition: A review. *Global Food Security, 6*, 24–33.

Domenech, L., & Ringler, C. (2013). *The impact of irrigation on nutrition, health and gender*. (IFPRI Discussion Paper 01259).

Dorward, A. R., & Chirwa, E. (2011). The Malawi agricultural input subsidy programme: 2005/06 to 2008/09. *International Journal of Agricultural Sustainability, 9*, 232–247.

Finckh, M. R., Naing, T. A. A., Kingsbury, A. J., & Buerkert, A. (2008). A survey of Myanmar rice production and constraints. *Journal of Agriculture and Rural Development in the Tropics and Subtropics, 109*, 151–168.

FAO. (2003). *Preliminary review of the impact of irrigation on poverty with special emphasis on Asia*. Rome: Food and Agriculture Organization, Land and Water Development Division.

FAO. (2014). *Statistical database (FAOSTAT)*. Rome: Food and Agriculture Organization.

Gebregziabher, G., Namara, R. E., & Holden, S. (2009). Poverty reduction with irrigation investment: An empirical case study from Tigray, Ethiopia. *Agricultural Water Management, 96*, 1837–1843.

Hanjra, M. A., Ferede, T., & Gutta, D. G. (2009). Reducing poverty in sub-Saharan Africa through investments in water and other priorities. *Agricultural Water Management, 96*, 1062–1070.

Huang, Q., Rozelle, S., Huang, J., Lohmar, B., & Wang, J. (2006). Irrigation, agricultural performance and poverty reduction in China. *Food Policy, 31*, 30–52.

Hussain, I., & Hanjra, M. A. (2004). Irrigation and poverty alleviation: Review of the empirical evidence. *Irrigation and Drainage, 53*, 1–15.

Igboji, C., Anozie, R. O., & Nneji, C. P. (2015). Analysis of socio-economic factors and profitability of rice production among small scale farmers in Ebonyi State. *Journal of Agriculture and Veterinary Science, 8*, 20–27.

Inocencio, A., Kikuchi, M., Tonosaki, M., Maruyama, A., Merrey, D., Sally, H., & de Jong, I. (2007). Costs and performance of irrigation projects: A comparison of sub-Saharan Africa and other developing regions. International Water Management Institute, Research Report 109, Colombo, Sri Lanka.

INSAE. (2011). *Rapport final de l'Enquête Modulaire Intégrée sur les Conditions de Vie des ménages* [Final report of the integrated modular survey on households living standards] (EMICoV, 2011). Benin: Institut National de la Statistique et de l'Analyse Economique.

INSAE. (2013). *Tableau de Bord Social 2012*. Benin: Institut National de Statistique et de l'Analyse Economique.

John, A., & Fielding, M. (2014). Rice production constraints and 'new' challenges for South Asian smallholders: insights into de facto research priorities. *Agriculture & Food Security, 3*, 18.

Kadigi, R. M. J., Tesfay, G., Bizoza, A., & Zinabou, G. (2012). Irrigation and water use efficiency in Sub-Saharan Africa. Global Development Network, Policy Research Paper 4, New Delhi.

Kamwamba-Mtethiwa, J., Namara, R., De Fraiture, C., Mangisoni, J., & Owusu, E. (2012). Treadle pump irrigation in MALAWI: Adoption, gender and benefits. *Irrigation and Drainage, 61*, 583–595.

Katic, P. G., Namara, R. E., Hope, L., Owusu, E., & Fujii, H. (2013). Rice and irrigation in West Africa: Achieving food security with agricultural water management strategies. *Water Resources and Economics, 1*, 75–92.

Koohafkan, P., Salman, M., & Casarotto, C. (2012). Investments in land and water. SOLAW Background Thematic Report – TR17. In FAO (Ed). 2011. *The state of the world's land and water resources for food and agriculture (SOLAW) - Managing systems at risk* (pp. 90–91). London/Rome: Food and Agriculture Organization of the United Nations/Earthscan.

Koundouri, P., Nauges, C., & Tzouvelekas, V. (2006). Technology adoption under production uncertainty: Theory and application to irrigation technology. *American Journal of Agricultural Economics, 88*, 657–670.

Lipton, M., Litchfield, J., & Faurès, J.-M. (2003). The effects of irrigation on poverty: A framework for analysis. *Water Policy, 5*, 413–427.

MAEP. (2010). *Stratégie Nationale Pour Le Développement de la Riziculture Au Benin*. Bénin: Ministère de l'Agriculture, de la pêche et de l'élévage.

MAEP. (2015). *Réalisations de la campagne agricole 2014–2015*. Bénin: Ministère de l'Agriculture, de la pêche et de l'élévage.

Mangisoni, J. H. (2008). Impact of treadle pump irrigation technology on smallholder poverty and food security in Malawi: a case study of Blantyre and Mchinji districts. *International Journal of Agricultural Sustainability, 6*, 248–266.

Mdee, A., Harrison, E. Mdee, C., Mdee, E., & Bahati, E. (2014). The politics of small-scale irrigation in Tanzania: Making sense of failed expectations. Working Paper 107, Future Agricultures.

Mdemu, M. V., Mziray, N., Bjornlund, H., & Kashaigili, J. J. (2016). Barriers to and opportunities for improving productivity and profitability of the Kiwere and Magozi irrigation schemes in Tanzania. *International Journal of Water Resources Development*. doi:10.1080/07900627.2016.1188267

Meinzen-Dick, R. S., & van der Hoek, W. (2001). Multiple uses of water in irrigated areas. *Irrigation and Drainage Systems, 15*, 93–98.

Mghase, J. J., Shiwachi, H., Nakasone, K., & Takahashi, H. (2010). Agronomic and socioeconomic constraints to high yield of upland rice in Tanzania. *African Journal of Agricultural Research, 5*, 150–158.

Mutiro, J., & Lautze, J. (2015). Irrigation in Southern Africa: Success or failure? *Irrigation and Drainage, 64*, 180–192.

Nonvide, G. M. A. (2016). Effect of irrigation adoption on rice yield in the municipality of Malanville, Benin. Paper presented at the Eleventh Edition of the African Economic Conference, Abuja, Nigeria, December 5–7.

Nouatin, G., Kougbadi, S., & Afouda, L. (2009). Analyse des contraintes de la production rizicole et les stratégies développées par les femmes de la commune de Gogounou. *Annales des Sciences Agronomiques, 12*, 45–59.

Ofosu, E. A., Van der Zaag, P., van de Giesen, N., & Odai, S. N. (2014). Success factors for sustainable irrigation development in Sub-Saharan Africa. *African Journal of Agricultural Research, 9*, 3720–3728.

Ogunjimi, L. A. O., & Adekalu, K. O. (2002). Problems and constraints of small-scale irrigation (Fadama) in Nigeria. *Food Reviews International, 18*, 295–304. doi:10.1081/FRI-120016207

Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark, S., … Nandagopal, S. (2004). Water resources: Agricultural and environmental issues. *Bioscience, 54*, 909–918.

Piza, C., & de Moura, M. J. S. B. (2016). The effect of a land titling programme on households' access to credit. *Journal of Development Effectiveness, 8*, 129–155. doi:10.1080/19439342.2015.1057859

Schut, M., Rodenburg, J., Klerkx, L., Hinnou, Léonard C., Kayeke, J., & Bastiaans, L. (2015). Participatory appraisal of institutional and political constraints and opportunities for innovation to address parasitic weeds in rice. *Crop Protection, 74*, 158–170.

Shah, T., van Koppen, B., Merry, D., de Lange, M., & Samad, M. (2002). *Institutional alternatives in African smallholder irrigation: Lessons from international experiences with irrigation management transfer*. International Water Management Institute Research report 60. Colombo, Sri Lanka.

Singh, R., Singh, R. K., & Singh, S. (2013). Enhancing rice and wheat production by bridging yield gap in western Uttar Pradesh of India. *Journal of Wheat Research, 5*, 43–47.

Sinyolo, S., Mudhara, M., & Wale, E. (2014). The impact of smallholder irrigation on household welfare: The case of Tugela Ferry irrigation scheme in KwaZulu-Natal, South Africa. *Water SA, Pretoria*, *40*, 145–156.

Smith, L. E. D. (2004). Assessment of the contribution of irrigation to poverty reduction and sustainable livelihoods. *International Journal of Water Resources Development, 20*, 243–257.

Tekana, S. S., & Oladele, O. I. (2011). Impact analysis of Taung irrigation scheme on household welfare among farmers in North-west Province, South Africa. *Journal of Human Ecology, 36*, 69–77.

Thanh, N. C., & Singh, B. (2006). Constraints faced by the farmers in rice production and export. *Omonrice, 14*, 97–110.

Totin, E., van Mierlo, B., Saïdou, A., Mongbo, R., Agbossou, E., Stroosnijder, L., & Leeuwis, C. (2012). Barriers and opportunities for innovation in rice production in the inland valleys of Benin. *NJAS – Wageningen Journal of Life Sciences, 60-63*, 57–66.

Turral, H., Svendsen, M., & Faures, J. M. (2010). Investing in irrigation: Reviewing the past and looking to the future. *Agricultural Water Management, 97*, 551–560.

Waddington, S. R., Li, X., Dixon, J., Hyman, G., & de Vicente, M.C . (2010). Getting the focus right: production constraints for six major food crops in Asian and African farming systems. *Food Security, 2*, 27–48.

You, L., Ringler, C., Wood-Sichra, U., Robertson, R., Wood, S., Zhu, T., … Sun, Y. (2011). What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. *Food Policy, 36*, 770–782.

Table A1. Constraints on irrigated rice production in the irrigation scheme of Malanville and farmers' proposed solutions.

Farmers' major constraints on irrigated rice farming	Rank	Causes	Farmers' proposed solutions
High cost of using irrigation	1	High cost of irrigation water High cost of other irrigation services	Reduce water fee Subsidy
Irrigation water is not available all the times	2	Frequent breakdown of pumps Irregular flow of river	Use of solar energy Regular repair and maintenance of the pump Dam construction
Flooding of fields	2	Poor drainage system Climate change	Improve drainage system Build dams/dikes Improve use of agro-meteorological services
Poor access to agricultural information	4	Poor extension services Lack of agricultural programme on the media	Improve extension services Develop agricultural programme on the media
Lack of agricultural machines	5	Poor agricultural mechanization policy	Improve agricultural mechanization policy
Unavailability of labour	5	Youth migration High labour requirement	Improve rural youth support programme Improve access to agricultural machines
Lack of agricultural credit	5	Problem of collateral High interest rates Lack of financial institution	Improve contract farming Provide loan guarantee Develop bank and microcredit facilities
Inadequate farmers' knowledge of water resources management	8	Lack of training on water resources management	Regular training on water resources management
Poor access to fertilizer and agro-chemicals	9	High cost of inputs Inputs targeted to other crops Late delivery	Input subsidies Develop agricultural inputs supply programme
Poor access to market	10	Value chain actors (traders, dealers, processors) are non-existent Road infrastructure underdeveloped	Develop rice value chain Develop road infrastructure
Unavailability of quality seed	11	Lack of training on quality seed production Poor information about the availability, characteristics and prices of quality seed Failed or rejected seed crops due to management problems	Build capacity of farmers to ensure sustainable supply of quality seed Improve quality seed distribution and marketing Develop seed production programme

Source: Field survey (2015).

Table A2. Constraints on rainfed rice production in the municipality of Malanville and farmers' proposed solutions.

Farmers' major constraints on rainfed rice farming	Rank	Causes	Farmers' proposed solutions
Lack of agricultural credit	1	Lack of financial institutions Problem of collateral High interest rates	Develop bank and microcredit facilities Improve contract farming Provide loan guarantees
Unavailability of high-quality seed	2	Lack of training on quality seed production Failed or rejected seed crops due to management problems Poor information on the availability, characteristics and prices of quality seed	Build capacity of farmers to ensure sustainable supply of quality seed Develop seed production programme Improve quality seed distribution and marketing
Inadequate farmers' knowledge of water resources management	3	Lack of training on water resources management	Regular training on water resources management
Poor access to agricultural information	4	Lack of agricultural programme on the media Poor extension services	Develop agricultural programme on the media Improve extension services
Poor access to market	5	Road infrastructure underdeveloped Value chain actors (traders, dealers, processors) are non-existent	Develop road infrastructure Develop rice value chain
Flooding of fields	6	Climate change	Build dams/dikes Improve use of agro-meteorological services
Poor access to fertilizer and agro-chemicals	7	Inputs targeted to other crops High cost of inputs	Develop agricultural inputs supply programme Input subsidies
Unavailability of labour	8	High labour requirement Youth migration	Improve access to agricultural machines Improve rural youth support programme
Poor land	9	Land used over a long period	Intensive use of fertilizers Use of fallow Use of manure
Lack of agricultural machines	10	Poor agricultural mechanization policy	Improve agricultural mechanization policy
Crop failure	11	High temperature stress	Fetch water/irrigation
Storage problems	12	Lack of modern storage facilities	Improve access to modern storage facilities

Source: Field survey (2015).