Agriculture and health: an overview of relationship between rice cropping systems and rice farmers' health in West Africa Rice Sector Development Hubs

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Abstract

The objective of this study was to examine the relationship between rice cropping systems and rice farmers' health to anticipate a possible public health problem that may arise in the long term because of rice production conditions in West Africa. Three thousand and fifty four producers of Rice Sector Development Hubs of ten West Africa countries were surveyed in 2013. The rice cropping systems were characterized using the factor analysis. The relationship between rice cropping systems and farmers' health was established with Analysis of Variance and linear regression. Three main rice cropping systems were identified in study area. The system 1 is the most harmful to the farmers' health and System 3 is the least harmful. The system 1 is characterized by three ecologies (Lowland / Irrigated / Mangrove), without association with other crops, the use of fertilizer (NPK, Urea, Organic fertilizer) and pesticide (Herbicide, Insecticide, Fungicide). These results strongly suggest the mechanization of rice production that will not only increase production but also to protect the farmers' health. Failing to mechanization, it is necessary to promote health protection and hygiene measures such as wearing boots, gloves, nose mask, etc.

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1. Introduction

Over the period 2000-2007, before the 2008 food crisis, the rice production growth rate per year for West Africa was 2.5% (Seck et al, 2013). The rice paddy yield growth rate per year for the same period and the same sub-region was -0.4%. The rice harvested area growth rate per year was 2.5%. The rice consumption growth rate per year was 4.2%. Generally in Africa, the annual production, yield, harvested area and consumption growth for the period 2000-2007 were respectively 3%, 0.3%, 2.3% and 4%. These figures show the importance of rice in West Africa, long before the 2008 food crisis. After the crisis, over the period 2007-2012, production increased by 9.7% per year in West Africa against 4.5% in Africa. The yield increased by 8% per year in West Africa against 2.6% in Africa. Harvested area increased by 1.6% per year in West Africa against 2.1% in Africa. Consumption of rice has increased by 9.7% per year in West Africa against an annual increase of 5.9% in Africa. Comparison of these figures before and after the 2008 food crisis shows that the rice economy has improved significantly in Africa in general and West Africa in particular after the 2008 food crisis.

The improvement in the rice economy in Africa in general and West Africa in particular can be explained by the enormous research efforts made by AfricaRice and its partners and an increased use of technological innovation after the rice crisis, such as improved varieties and improved crop management in general. This was proved by the annual growth rate of the yield in West Africa, which increased from -0.4% before the crisis to 8% after the crisis. To continue to support this effort, a synergy of action has been developed between the different areas of research, namely: Genetic Diversity and Improvement; Crop and Natural Resources Management; Policy, Impact Assessment and Rice Value Chain Development (Tollens et al, 2013).

Apart from the importance of research in improving the Africa's rice economy, we one must also recognize the bravery of producers who engage heavily in rice production. In 2009, more than 7,455,012 African households grew rice (Diagne et al, 2013). In West Africa, there were in 2009, at least 3,824,368 rice households with an average size of 8 persons per household. When added to the member of the household, farm workers, one realizes that millions of Africans in general and West Africa in particular are involved in rice production. For most of them, rice is the main activity and they work in rice cropping systems characterized mainly by lowland ecology, lack of mechanization, application of pesticides without hygiene and safety standards, etc. These systems could harm the health of actors involved in the rice production. The objective of this paper is to examine the relationship between rice cropping systems and rice farmers' health to anticipate a possible public health problem that may arise in the medium and long terms because of rice production conditions in West Africa.

2. Theoretical framework: Linkages between agriculture and health

Agriculture and health are linked in several ways (Figure 1). Agriculture influences health and vice versa. This framework was developed by Hawkes and Ruel (2006) for understanding the linkages between agriculture and health. The human organism needs a certain number of basic foods to be healthy. Most of this food need by human organism is made available by agriculture, but some agricultural products can also lead to health problems if they are contaminated with food-borne diseases. The health of those involved in the agricultural production is also affected by agricultural production systems which interact with environmental variables such as water, soil and air. For example, lowland and mangroves can create favorable conditions for the growth of parasitic vectors such as malaria, schistosomiasis, and river blindness. For instance, characteristics of agricultural production systems, such as crop rotation, the presence of livestock, and the proximity of villages to fields and water sources, create favorable conditions for contracting waterborne vector diseases (World Bank, 2007). As agriculture affects the health of farmers, the health of farmers and their workers also affects agriculture. Actors who are in poor health cannot do a lot of work. This causes a reduction in the productivity and income and in the long-term, worsening poverty. So it's a vicious circle Agriculture – Health, Health - Agriculture.

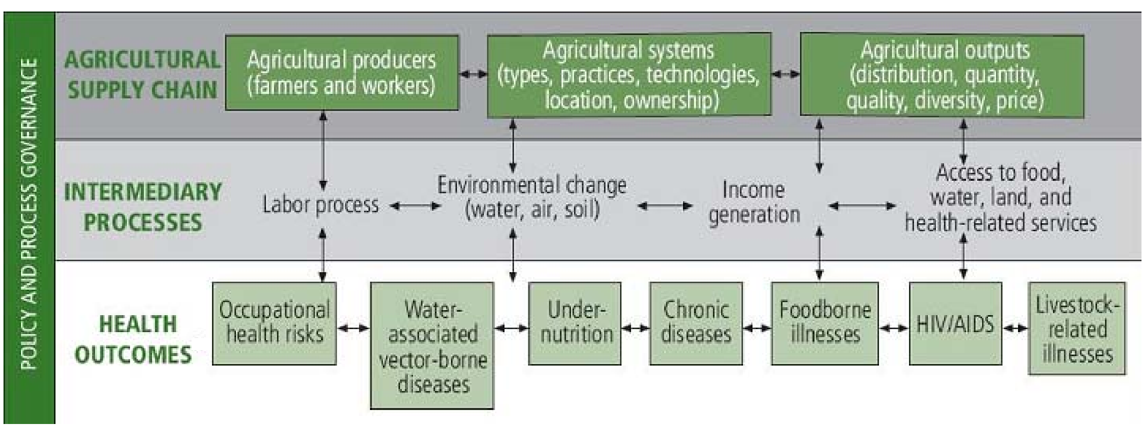

Figure 1: Framework for linkages between agriculture and health.
Source: Hawkes and Ruel (2006)

3. Materials and Methods

3.1. Study area, sampling design and data collection

Data were collected in Rice Sector Development Hubs (RSDH) of 10 West Africa countries named Benin, Burkina Faso, The Gambia, Ghana, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo. RSDH are zones where rice research products from the Consortium Research Programs and the task forces are integrated across the rice value chain to achieve development outcomes and impact (AfricaRice, 2011). Hubs represent the key ecologies and different market opportunities across African countries (Figure 2).

Thirty-two villages were selected in each hub based on the accessibility, ecologies and the importance of rice production. Ten producers were randomly selected in each village. In total, three hundred and twenty producers were surveyed by hub giving a total of 3054 producers from 10 African countries.

Data collection covered the period 2011-2012 crop season. The questionnaire was developed on the web based application called Mlax. The tablets Google Nexus 7 were used in the field for data collection.

3.2. Data processing

3.2.1. Categorization of rice cropping systems

The factor analysis was used to categorize the rice cropping systems. This method is a multivariate analysis statistical technique usually used for data reduction. It allows reducing the number of variables in an analysis by describing linear combinations of the variables that contain most of the information (Afifi et al, 2012). It finds a few common factors q that linearly reconstruct the *p* original variables.

$$y_{ij} = z_{i1}b_{ij} + z_{i2}b_{2j} + \cdots + z_{iq}b_{qj} + e_{ij}$$

Where y_{ij} is the value of the i^{th}observation on the j^{th} variable, z_{ik} is the i^{th} observation on the k^{th} common factor, b_{kj} is the set of linear coefficients called the factor loadings, and e_{ij} is similar to a residual but is known as the j^{th} variable's unique factor. Everything except the left-hand-side variable is to be estimated.

Eleven dichotomous categorical variables were introduced in this model. We distinguish variables related to ecology (lowland, upland, irrigated and mangrove). The value 1 is assigned if the producer grows rice in the ecology and 0 otherwise. The variables related to crops associated with rice (other cereals, leguminous plants, and truck farming products). The value 1 is assigned if the producer combines rice with one crop of these groups under the same plot. The value 0 is assigned otherwise. The variables related to the use of fertilizer (npk, urea and organic fertilizer). The producer takes the value 1 if using fertilizer and 0 otherwise. The use or not of pesticide was also included in the model. The value 1 is assigned if the producer uses herbicides, insecticides or fungicides. It takes the value 0 if it does not use any of these products.

Let's assume that Ψ represent the $p \times q$ diagonal matrix of uniquenesses, and let Λ represent the $p \times q$ factor loading matrix. Let f be a $1 \times q$ matrix of factors. The standardized vector of observed variables $X(1 \times p)$ is given by the system of regression equations (Mulaik, 2010 ; Rencher and Christensen, 2012) as follows:

$$X = f\Lambda' + e$$

Where e is a $1 \times p$ vector of errors with diagonal covariance equal to the uniqueness matrix Ψ. The common factors f and the specific factors e are assumed to be uncorrelated.

Under the factor model, the correlation matrix of$X$, calledΣ, is decomposed by factor analysis as follows:

$$\Sigma = \Lambda\Phi\Lambda' + \Psi \text{ with } \Phi = \mathrm{I}$$

3.2.2. Specification of relationship between rice cropping systems and illness cases

One-way Analysis of Variance model (Snedecor and Cochran, 1989) was used to identify the existence of relationship between rice cropping systems and mean illness cases of household. The response variable include in the model is the average number of sickness case per household. The factor variable is the rice cropping systems. We distinguished three rice cropping systems based on the factor analysis.

The multiple linear regression model is used to explain the relationship between rice cropping systems and the average number of illness cases per household.

Model 1:

$$msick = \beta_0 + \beta_1 cropsys1 + \beta_2 cropsys2 + \varepsilon$$

Where, *msick* is the average number of illness cases per household (Total illness cases of the household / Household size). The terms *cropsys1* and *cropsys2* are dichotomous categorical variables representing the rice cropping system number 1 and 2 respectively. The value 1 is given to the household 1 if relevant and 0 otherwise. The parameter β_i represents the regression coefficient to be estimated. The *cropsys3* is not included in the model to avoid the multicolinearity problem. It is used as the base in the interpretation of the results. The robust standard error is obtained by fixing the heteroskedasticity problems.

Model 2:

$$msick = \beta_0 + \beta_1 lowland + \beta_2 upland + \beta_3 irrigated + \beta_4 mangrov + \beta_5 npk + \beta_6 urea + \beta_7 ofertilizer + \beta_8 pesticide + \beta_9 maize + \beta_{10} legum + \beta_{11} truck + \beta_{12} training + \beta_{13} agric + \beta_{14} expert + \epsilon$$

Tableau 1 presents the variables included in the models. β_i represents the regression coefficients with *i*= 0, 1, …,14.

4. Results and discussions

4.1.Characteristic of surveyed households

Tables 2a and 2b present the characteristics of surveyed households. The analysis of this table shows that 82% of surveyed household heads are men against 18% of women. Most of the household heads (82%) were married and agriculture was their main activity (78%). Almost half of them (43%) had no formal education level. However, there are 25% of household heads literate. Very few household heads (28%) were trained in the field of rice production. Half of them are members of an association.

On average, household heads were aged 50 years old. The youngest was 20 and the oldest 72 years old. The average household size was nine (09) persons and one person was sick in average 2 times over the last twelve months preceding the surveys. The number of years of experience of surveyed farmers in rice production varies from 1 to 47 years. On average, farmers have sixteen years of experience in this activity. Average health spending per capita and per year in the households is 69 US Dollars. With regard to rice production, there is an average 3.8 ha of rice grown per household with an average yield of 3.6 tons / ha.

4.2. Categorization and characteristics of rice cropping systems

Four factors were used to characterize cropping systems (Table 3). There are ecologies, the association or not of crops, the use or not of fertilizers and the use or not of pesticides. 70% of the surveyed households have at least one plot of rice in lowland, 51% in upland, 17% in irrigated and 4% in mangrove. Regarding the association of crops, rice plots are associated with the truck farming products in 11% of cases, the cereals in 8% of cases and leguminous plants in 1% of cases. Three types of fertilizers are used: NPK in 37% of cases, Urea 40% of cases and organic fertilizer in 40% of cases. Most of the households (60%) use pesticides in their rice plot. This can be herbicide, insecticide or fungicide.

Tables 4, 5 and 6 present the results of analysis of principal factors. Based on the cumulative proportions of eigenvalues, one retains the first three factors which concentrate about 90% of the information. Each factor represents a rice cropping system.

The rice cropping system 1 (Cropsys1) is characterized by ecologies such as Lowland, Irrigated, and Mangrove without association of rice with other crops, the use of fertilizer (NPK, Urea, Organic fertilizer) and the use of pesticide (Herbicide, Insecticide, Fungicide).

The rice cropping system 2 (Cropsys2) is characterized by ecologies such as Lowland, Upland and Irrigated), the association of rice with other cereals, the use of fertilizer (NPK) and without pesticide.

The rice cropping system 3 (Cropsys3) is characterized by upland and irrigated ecologies as and , association of rice with other crops (Leguminous / Truck farming products), no fertilizer and no pesticide.

4.3. Relationship between rice cropping systems and farmers' health

Figure 3 presents the boxplot of mean illness cases per capita by rice cropping systems. The analysis of this graph shows that on average, a person living in a household of the rice cropping system 1 got sick five times over the last twelve months preceding the survey. An average of 2 sickness cases is noted in the cropping system 2 and less than one case of sickness over the last twelve months in the cropping system 3.

The results of the Analysis of Variance of the average number of illness cases between the different cropping systems are shown in Table 7. These results allow saying that there is a significant difference at 1% between the mean frequencies of illness cases. In other words, the average number of illnesses per person varies from one rice cropping system to another. The multiple comparisons using Tukey's test revealed that all production systems taken in pairs differentially affect the health of producers and the differences are significant at 1%. As a result, the farmers' health is more vulnerable to the system 1 than the system 2.

Table 9 shows the results of the regression between the characteristics of rice cropping systems and the rice farmers' health. The model is globally significant at 1%. 73% of the changes in the average number of illness cases per household are explained by changes in explanatory variables included in the model. The analysis shows that the type of ecology used, the use or not of pesticide, the cultivated area of rice, the number of years of experience in rice production, the main activity and the training in rice production affect the average number of illness cases per household. Of all the characteristics of the rice cropping systems, the type of fertilizer used and the type of crop associated to rice does not have a significant effect on the rice farmers' health.

Having grown rice in lowland or in mangroves increased respectively by 0.6 and 0.5 units the average frequency of illnesses per household. Contrariwise, upland ecology reduces this frequency by 0.7. Regarding the use of pesticide, it increases the average frequency of household illness cases by 1 unit over twelve months. Moreover, the average frequency of illnesses per household increases with the size of rice cultivated area and the number of years of experience. We deduce that the farmers growing a large area of rice and having large experience in rice are more exposed to illness.

Table 10 shows the direct relationship between the rice cropping systems identified and average frequency of illnesses per household. The model is globally significant and 69% of illness cases in the surveyed households are due to the rice cropping systems. The results also show that the cropping system 1 increases the average frequency of illnesses by 5 units from the cropping system 3 while the cropping system 2 increases the average frequency of illnesses by about 2 units from the cropping system 3.

Conclusions

Rice cropping systems affect the health of farmers involved in rice production. Systems based on lowland and mangrove ecologies and using pesticides are the most dangerous to the health of farmers. These ecologies create favorable conditions for the growth of parasitic vectors such as malaria, schistosomiasis, and river blindness. Regarding pesticides, whether herbicides, insecticides or fungicides should be applied by taking all necessary safety precautions. Unfortunately, the producers generally do not even take the trouble to protect their nostrils before spraying pesticides. Aided by the wind, some of the pesticides sprayed deposits in their organism, causing diseases of all kinds.

These results strongly suggest the mechanization of rice production that will not only increase production but also to protect the farmers' health. Failing to mechanization, it is necessary to promote health protection and hygiene measures such as wearing boots, gloves, nose mask, etc. Farmers need to be informed about the health risks related to rice cropping systems. Similarly, they must be trained on methods and strategies to use to protect their health.

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Appendix

<u>Table 1</u>: Description of variables introduced in the models

Variable	**Description**	**Type**
msick	Average number of sickness cases per household (Total sicknes cases of the household / Household size)	Numeric, continuous
lowland	Using lowland ecology	Dichotomous dummy (0; 1)
upland	Using upland ecology	Dichotomous dummy (0; 1)
irrigated	Using irrigated ecology	Dichotomous dummy (0; 1)
mangrov	Using mangrove ecology	Dichotomous dummy (0; 1)
npk	Using NPK fertilizer	Dichotomous dummy (0; 1)
urea	Using urea fertilizer	Dichotomous dummy (0; 1)
ofertilizer	Using organic fertilizer	Dichotomous dummy (0; 1)
pesticide	Using pesticide (Herbicide Insecticide Fungicide)	Dichotomous dummy (0; 1)
cereals	Associated maize with rice on the same plot	Dichotomous dummy (0; 1)
legum	Associated leguminous plants with rice on the same plot	Dichotomous dummy (0; 1)
truck	Associated truck farming products with rice on the same plot	Dichotomous dummy (0; 1)
training	Received agricultural training	Dichotomous dummy (0; 1)
agric	Having agriculture as main activity	Dichotomous dummy (0; 1)
expert	Number of years of experience in rice production	Numeric, continuous

Table 2a: Characteristic of surveyed household (categorical variables)

Characteristic		Frequency	Relative frequency (%)
Sex	Male	2503	81.9
	Female	551	18.1
Marital status (married)		2510	82.2
Education level	None	1322	43.3
	Primary school	442	14.5
	Secondary school	428	14.0
	University	99	03.2
	Literacy	763	25.0
Main activity (agriculture)		2378	77,9
Training in rice cropping		843	27.6
Membership in association		1508	49.4

Table 2b: Characteristic of surveyed household (numeric continuous variables)

Characteristic	Mean	Standard deviation	Minimum	Maximum
Age (years)	49.8	13.2	20	72
Household size (person)	9.4	5.6	1	36
Number of sickness cases/capita	2.3	1.4	0	13
Experience (years)	16.2	11.4	1	47
Health expenditure /capita ($)	68.7	17.3	0	89.6
Area (ha)	3.8	2.7	0.7	11
Yield (ton)	3.6	1.4	0.8	4.9

Table 3: Characteristic of rice cropping systems

Characteristic		Frequency	Relative frequency (%)
Ecology	Lowland	2129	69.7
	Upland	1568	51.3
	Irrigated	513	16.8
	Mangrove	108	3.5
Crop association	Cereal	236	7.7
	Leguminous plan	33	1.1
	Truck farming products	324	10.6
Use of fertilizer	NPK	1134	37.1
	Urea	1228	40.2
	Organic fertilizer	1220	40.2
Use of pesticide		1838	60.2

Table 4: Principal factors analysis

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.88729	2.88221	0.6557	0.6557
Factor2	1.00508	0.58422	0.1695	0.8252
Factor3	0.42086	0.21641	0.071	0.8962
Factor4	0.20445	0.01466	0.0345	0.9307
Factor5	0.1898	0.02461	0.032	0.9627
Factor6	0.16518	0.12969	0.0279	0.9906
Factor7	0.03549	0.02361	0.006	0.9966
Factor8	0.01187	0.00509	0.002	0.9986
Factor9	0.00679	0.00492	0.0011	0.9997
Factor10	0.00187	0.00211	0.0003	1

LR test: independent vs. saturated: chi2(55) = 3.7e+04 Prob>chi2 = 0.0000

Table 5: Factor loadings (pattern matrix) and unique variances

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Uniqueness
Lowland	0.6808	0. 1565	-0.0609	0.0836	0.1109	0.18	0.0527	-0.0079	-0.0004	-0.0011	0.5126
Upland	-0.1347	0.5264	0.38	-0.0546	0.0489	-0.0232	-0.0657	0.0344	-0.0063	-0.0004	0.5489
Irrigated	0. 2804	0.0479	0.2491	0.1674	0.0735	0.1318	-0.0055	0.0503	-0.017	-0.0034	0.6525
Mangrove	0. 5206	-0.0519	-0.0672	0.154	-0.2512	0.2373	-0.0273	-0.0045	0.0049	0.0015	0.8461
Cereals	-0.1444	0.0177	-0.3501	0.1619	0.2473	-0.0211	-0.0496	0.0235	-0.0032	0.0001	0.7654
Leguminous	-0.0148	-0.0292	0.2657	0.2717	0.0744	-0.1003	0.0404	-0.0547	0.0169	0.003	0.834
Truck farming products	-0.0852	-0.2331	0.0929	-0.2015	0.1837	0.1992	0.0604	-0.0192	0.0056	0.0018	0.8117
NPK	0.9291	0.0704	-0.0616	0.0433	-0.0628	-0.0776	0.1228	0.0382	-0.0206	-0.0019	0.0991
Urea	0.9948	-0.0616	-0.0158	-0.0098	0.0213	0.0206	-0.0176	0.0239	0.0645	0.0103	0.0001
Organic fertilizer	0.9952	-0.0579	-0.0145	-0.0097	0.0284	0.0292	-0.0448	-0.0317	-0.0043	-0.0332	0.0002
Pesticide	0.994	-0.057	-0.0126	-0.0081	0.031	0.0328	-0.0498	-0.0335	-0.0388	0.0252	0.0007

Table 6: Rice cropping systems in the study area

Characteristics	Rice cropping systems		
	Cropsys1	Cropsys2	Cropsys3
Ecology	Lowland, Irrigated, Mangrove	Lowland, Upland, Irrigated	Upland, Irrigated
Crops association	No association	Cereals	Leguminous, Truck farming products
Use of fertilizer	NPK, Urea, Organic fertilizer	NPK	No fertilizer
Use of pesticide	Herbicide, Insecticide, Fungicide	No pesticide	No pesticide

Table 7: Analysis of Variance of mean sickness cases per capita

Source	SS	df	MS	F	Prob > F
Between groups	3905.55	2	1952.78	4837.89	0.0000
Within groups	1032.92	2559	0.40		
Total	4938.47	2561	1.93		
Bartlett's test for equal variances: chi2(2) = 1.3e+03 Prob>chi2 = 0.000					

Table 8: Multiple comparisons, Turkey test on mean sickness cases per capita

Cropping systems		Mean difference	Standard error
Cropsys1	Cropsys2	3.6***	0.057
	Cropsys3	5.1***	0.057
Cropsys2	Cropsys1	-3.6***	0.057
	Cropsys3	1.5***	0.026
Cropsys3	Cropsys1	-5.1***	0.057
	Cropsys2	-1.5***	0.026

****=Significant at 1%*

Table 9: Relationship between rice cropping systems characteristics and farmers' health

msick	Coefficient	Standard error	t
lowland	0.55***	0.11	5.06
upland	-0.65***	0.07	-9.23
irrigated	-0.04	0.09	-0.45
mangrov	0.47**	0.18	2.58
npk	0.20	0.21	0.96
uree	0.23	0.71	0.32
ofertilizer	-1.07	1.53	-0.70
pesticide	0.97***	0.26	3.69
truck	-0.36	0.61	-0.56
area	0.04**	0.02	2.12
expert	0.33**	0.13	2.53
agric	0.06**	0.03	2.20
training	-0.42***	0.07	-5.80

Number of observation: 2562
F(13, 2548) = 15.70
Prob > F = 0.0000
Adj R-squared = 0.73

****=Significant at 1%, **= significant at 5%*

Table 10: Relationship between rice cropping systems and farmers' health

msick	Coefficient	Standard error	t
cropsys1	5.13***	0.06	90.09
cropsys2	1.53***	0.03	59.09
constant	0.30***	0.02	16.47

Number of observation: 2562
F(2, 2559) = 4837.89
Prob > F = 0.0000
Adj R-squared = 0.69

****=Significant at 1%*

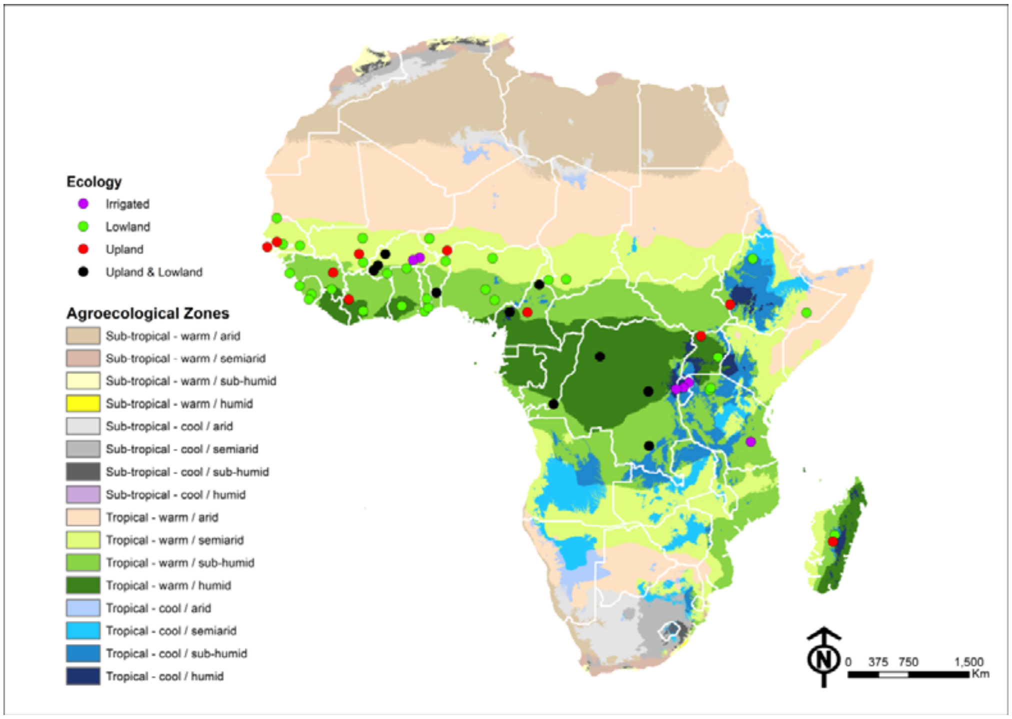

Figure 2: Key ecologies in the Rice Sector Development Hubs
Source:

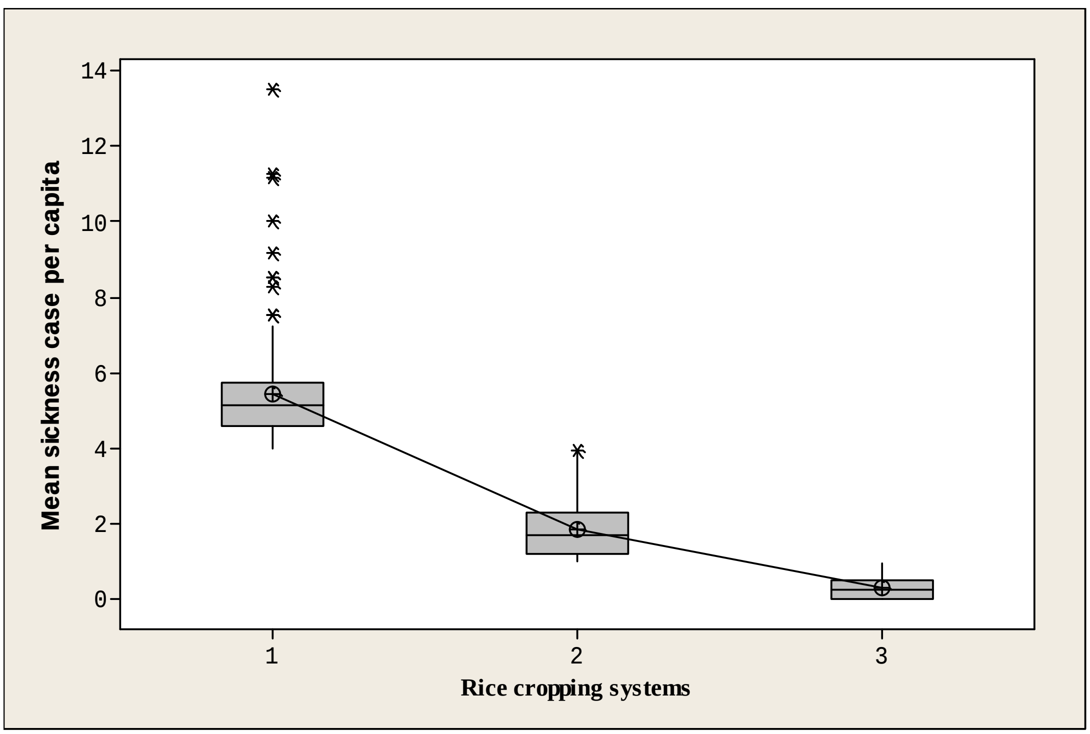

Figure 3: Boxplot of mean sickness cases per capita by rice cropping systems

Picture 1: Example of farmers working in the rice cropping system 1
Source: