academicJournals

Vol. 11(20), pp. 221-229, 30 October, 2016
DOI: 10.5897/SRE2016.6424
Article Number: D85C6CC61053
ISSN 1992-2248

http://www.academicjournals.org/SRE

Scientific Research and Essays

*Full Length Research Paper*

# Lessons withdrawn from the diversity of inland valleys cultivation at a regional scale: A case study of Mono and Couffo departments in south Benin

**Luc Ollivier Sintondji[1]*, Joël Huat[2,4], Elliott Dossou-Yovo[1], Jean Louis Fusillier[3], Euloge Agbossou[1], Justin Djagba[4] and Félix Gbaguidi[5]**

[1]University of Abomey- Calavi / Faculty of Agronomy Sciences, Benin Republic.
[2]CIRAD, UR Hortsys, F-34398, Montpellier Cedex 05, France.
[3]CIRAD, UMR G-Eau, F-34398, Montpellier Cedex 05, France.
[4]Africa Rice Center, 01 BP 2031, Cotonou, Benin Republic.
[5]Cellule Bas-fond / Direction du Génie Rural/ MAEP/Porto-Novo, Benin Republic.

Received 21 May, 2016; Accepted 21 September, 2016

**In a context of greater climate variability and increasing population pressure, inland valleys are considered as high potential agricultural area. This agricultural potential has been subject to multiple initiatives for characterization which were generally based on the physical characteristics. However, support strategies based on such inventories often fail to fit with the promoters' expectations. One of the reasons is that approaches used to classify inland valleys do not generally take into account socio-economic factors. This study aims to characterize the diversity of inland valleys in the departments of Mono and Couffo based on a joint consideration of biophysical, agronomic and socio-economic characteristics and to prioritize the factors affecting their agricultural use. Data were collected on 158 inland valleys and were related to biophysical characteristics, uses, management and economic productivity. Six types of inland valleys differentiated by the production systems, economic productivities and socioeconomic characteristics were identified. The production system based on rainfed rice and off-season vegetable with application of chemical fertilizer generated the highest economic productivity. Strengthening farmers' technical abilities was important for a better capitalization on inland valleys. These results support the importance to combine several approaches in the classification of inland valleys and to fully understand the factors affecting their valorization by rural populations.**

**Key words:** Diversification, inland valleys, intensification, performance, typology, uses.

## INTRODUCTION

The rapidly growing population in Sub-Saharan Africa (SSA) necessitates an increase in food production. Inland

*Corresponding author. E-mail: o_sintondji@yahoo.fr.

**Table 1.** Values (mean and standard error) of surface soil characteristics (0-20 cm) of the dominant soil types of the study area.

| Sites | pH | OC (%) | N (%) | P (ppm) | K (%) |
|---|---|---|---|---|---|
| Lixisol | 0.90±0.21 | 0.07±0.01 | 10.40±3.36 | 1.87±0.81 | 6.51±0.24 |
| Gleysol | 0.94±0.15 | 0.07±0.01 | 15.90±12.34 | 0.24±0.05 | 6.72±0.20 |

Source: Igué et al. (2013).

valleys offer extensive potential for agricultural production (Faure, 2005). Inland valleys can be defined as waterlogged areas where the water of small catchments converges (Andriesse and Fresco, 1991). The flooding character of this area, the relative difficulty to manually till the soils often dominated by clay and weed pressure have been for long time the major obstacles to their cultivation (Windmeijer et al., 2002). However, in a context of greater climate variability and increasing pressure on uplands, the privileged hydrological conditions of inland valleys make them a great agricultural potential area for flood-tolerant crops such as rice and for off-season production (Giertz et al., 2012). Thus, the agricultural potential of inland valleys has been subjected since the 1980s to many initiatives for inventory and characterization (Legoupil et al., 2000).

Approaches used to classify inland valleys were generally based on the conditions of the physical environment: climate, morphology, pedology and hydrology (Windmeijer and Andriesse, 1993). This physical knowledge of inland valleys was the basis for public policies to support their agricultural use with hydraulic structures, especially in the Sudanese region (Ahmadi, 1998). The results obtained by the development projects in inland valleys, however, rarely reached the expectations and objectives of the promoters. The causes of this mixed assessment included the lack of control on the water regimes of inland valleys due to their complexity and the negligence of socio-economic factors (Ahmadi, 1998; Onyeweaku et al. 2010; Umeh and Chukwu, 2013). Thus, a better knowledge of the physical and socioeconomic components of inland valleys appeared to be necessary to guide interventions for their agricultural use.

At a regional scale, with the objective to diagnose agricultural constraints and potentials, it has rarely been applied characterization approaches combining biophysical, socio-economic and agronomic dimensions. This study is specifically designed to test this integrated approach by using multi-factor analysis, an original method that differs from the other integrated analysis, such as those of Sakané et al. (2011). The specific objectives of this study were (i) to characterize the diversity of inland valleys of the departments of Mono and Couffo in southern Benin by establishing a typology based on a combined consideration of biophysical, agronomic and socio-economic factors; (ii) to identify and prioritize the factors affecting the agricultural use of inland valleys.

## MATERIALS AND METHODS

### Study area

The departments of Mono and Couffo are located in southern Benin between 1°15' E and 2°10' E and 6°15' N and 7°30 N. The climate of the study area is sub-equatorial with two rainy seasons alternating with two dry seasons. Annual precipitation fluctuates between 800 and 1000 mm. Air temperature slightly varies within the season. The mean annual air temperature is around 27°C. The dominant types of soil are Lixisols and Gleysols (Table 1) (Youssouf and Lawani, 2000). The main economic activities are agriculture, fishing, breeding, transformation of agricultural products, handicrafts and trade. The crops mostly cultivated are maize, rice, tomato, pepper, okra, leafy vegetables, cowpeas, groundnuts and cassava (Dossou et al., 2006; Ogouwalé, 2006; Amoussou, 2010).

### Data collection and processing

Data collection was done in two steps: identification of inland valleys and their mapping (limits of the area subject to flooding, coordinates of the center) with the Global Positioning System receiver and administration of questionnaires to the users of inland valleys. Visits in inland valleys were made by investigators to assess the biophysical characteristics. Soil texture and fertility were evaluated according to farmers' knowledge and perception. Soil texture was assessed by feeling the weight and rubbing soil between fingers. Soil fertility was assessed based on observable plant and soil related characteristics namely; soil colour, crop yield, soil water holding/retention capacity, stoniness, difficulty to work soil, type and abundance of indicator weeds, colour of leaves and deficiency symptoms observed on crops, crop growth rate and presence and abundance of soil macro-fauna (Table 2). The flood heights in the different parts of the inland valleys were evaluated with a graduated vertical stick. Focus groups were conducted to harmonize the answers of the interviewees on soil texture, fertility and hydrological characteristics of the inland valleys. In total, 158 inland valleys were identified from a comprehensive inventory (Figure 1). The typology of inland valleys was based on multivariate analysis. This is an integrated approach that allows understanding the interactions between land uses, socio-economic and biophysical characteristics of the environment (Sakane et al., 2011). Data processing consisted of the realization of multiple factor analysis and hierarchical cluster analysis with R software.

#### *Multiple factor analysis*

Multiple factor analysis (MFA) is a multi-factorial table method.

**Table 2**. Indicators of soil fertility.

| Indicator | Fertile soils | Infertile soils |
|---|---|---|
| **Crop performance** | | |
| Crop growth rate | Fast/high growth rate | Stunted and slow plant growth |
| Crop yield | Consistently high yields | Low yields |
| Colour of leaves of growing crops | Large green leaves | Small/ stunted yellowish leaves |
| **Soil characteristics** | | |
| Soil colour | Dark colour | White/pale/light |
| Moisture holding capacity | High | Low |
| Soil workability | Easy to work | Difficult to work |
| Stoniness of soil | Few stones and pebbles present | Numerous stones and pebbles present |
| **Biological characteristics** | | |
| Presence of worm casts | Numerous wet worm casts | Few worm casts |
| Presence of soil macro-fauna | Earthworms, beetles and millipedes present | Few |
| Presence of indicator weeds | *Chromolaena odorata* with large green leaves | - *Chromolaena odorata* with small yellow leaves<br>- Grassy weeds |

Beyond the theoretical approaches (Escofier and Pagès, 1984), few applications were made in agriculture. One of these applications was conducted on livestock farms by Alary et al. (2002). The advantage of this method is its ability to combine a global analysis using various types of data and a partial analysis focusing on each group of data. The MFA allows highlighting the relationships between variables grouped into themes by searching for common factors of differentiation of statistical units. In this study, the statistical unit was the inland valley. The data set was divided into a series of tables; each table corresponded to a group of variables that described a component of the inland valley.

The themes used in this study covered the following components:

i) the "biophysical" component informed about the physical characteristics (area, soil texture, fertility) and hydrological characteristics (beginning, duration, height of flooding and drainage) of inland valley;
ii) the "agricultural" component was divided into two sub-themes (a) the production system according to the combination of crops practiced and the levels of inputs used, (b) the agricultural performance in terms of economic productivities (gross product per hectare) and cropping intensity;
iii) the component "economical environment" described market access and facilities of the town or village and the presence of support structures for agricultural development.

The analysis focused on four themes bringing together sixteen variables. The variables were broken into forty-six modalities based on the distribution of the values of each variable in order to obtain balanced frequencies (Table 3).

***Hierarchical ascendant classification (HAC)***

Hierarchical ascendant classification was conducted to subdivide the 158 inland valleys into classes; each class consisting of relatively homogeneous inland valleys.

## RESULTS

### Factors structuring the diversity of inland valleys agricultural uses

For each theme, the key factors that differentiated the sample of inland valleys were identified (Figure 2). Two major groups of inland valleys were identified. At the positive side of the axis 2, there was a first group of inland valleys whose farmers benefited from the technical support of projects and used chemical fertilizers. The farmers of this group of inland valleys had a production system based on off-season vegetable with high economic productivity. During the rainy season, some of these inland valleys were cultivated with maize with high productivity (dial: axis 1 negative, axis 2 positive). Others, meanwhile, were cultivated during the rainy season in vegetable with low productivity (Dial: axis 1 positive, axis 2 positive). The cropping intensity of this group of inland valleys was medium to high. At the negative side of the axis 2, there was a second group of inland valleys cultivated mainly during the rainy season with rice with a moderate productivity (dial: axis 1 negative, axis 2 negative). Therefore, technical support of projects, use of chemical fertilizers, production system and economic productivity were the major factors structuring the diversity of inland valley agricultural uses.

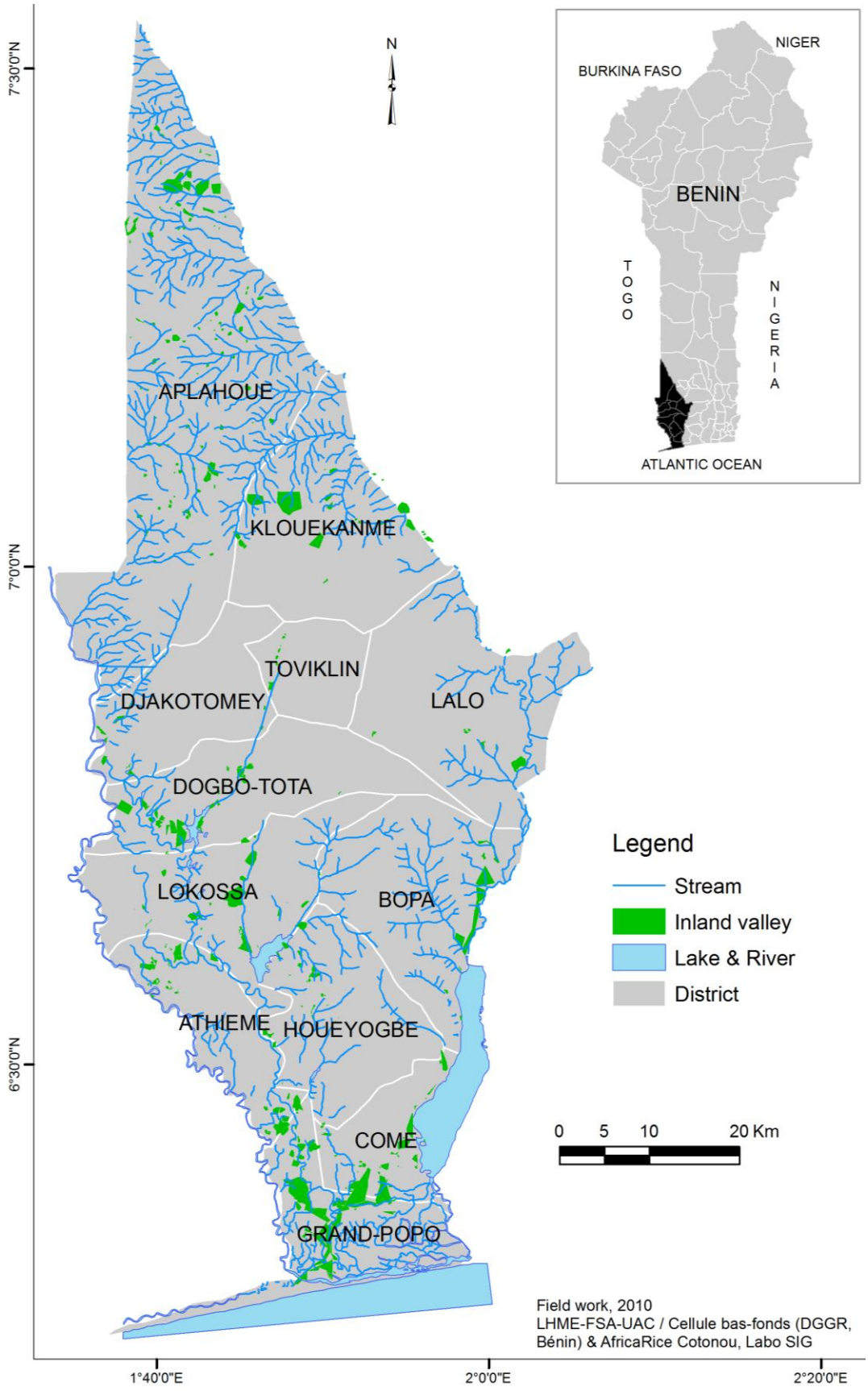


**Figure 1.** Location of the Mono and Couffo departments and the inventoried inland valleys.

**Table 3.** Themes and selected variables.

| Themes | Variables |
|---|---|
| Physical and hydrological environment | Area of inland valley, beginning of flooding, duration of flooding, height of flooding, soil fertility |
| Agricultural performance | Gross income in rainy season, gross income in dry season, cropping intensity |
| Production system | Cropping system in rainy season, cropping system in dry season, use of chemical fertilizer |
| Socioeconomic environment | Distance inland valley to village, store in the village, rice miller in the village or in the district of the village, support to inland valley farmers and accessibility to village |

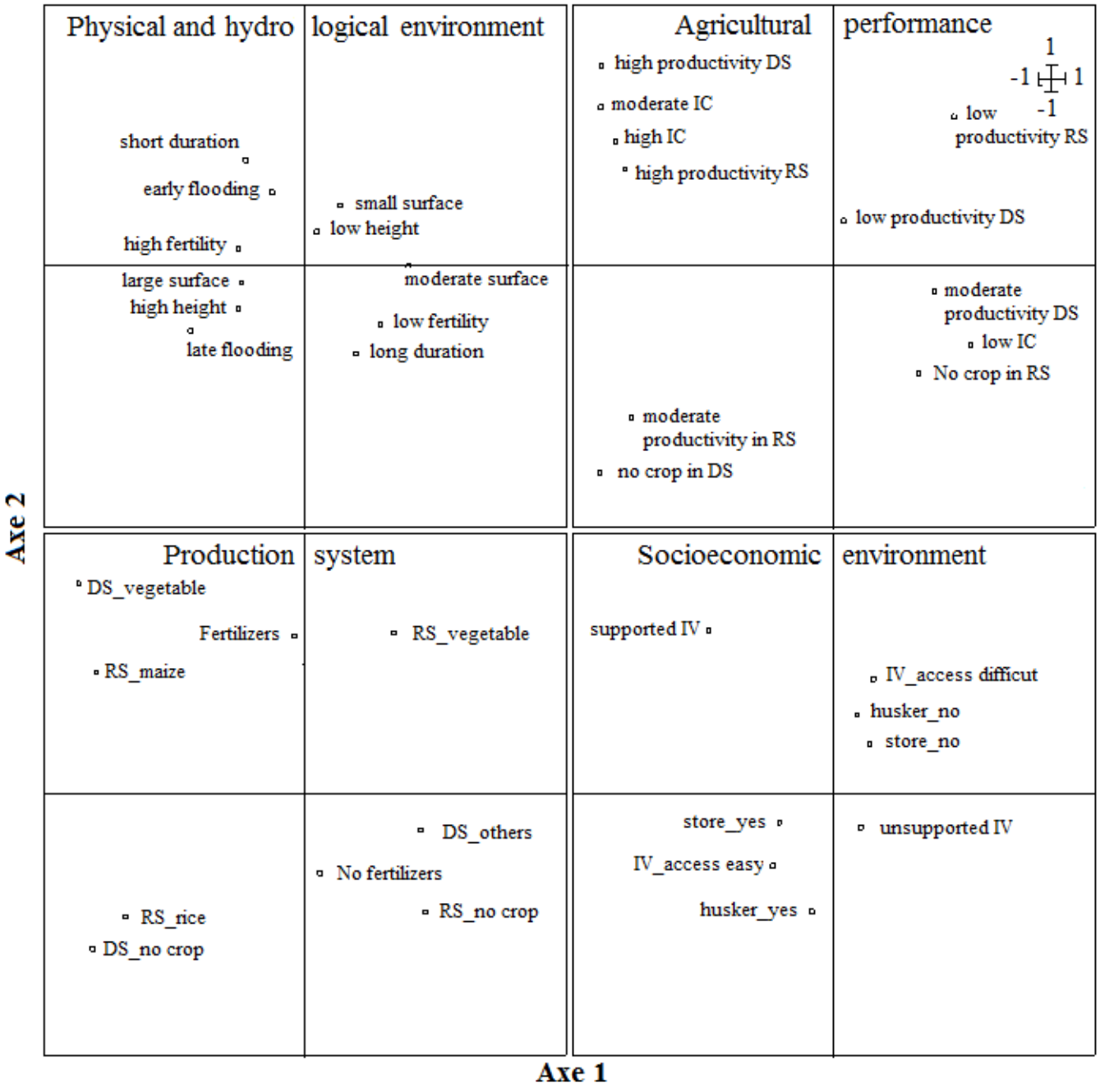


**Figure 2.** Projection of the modalities of each theme on the factorial plan 1 x 2. IC: cropping intensity; IV: inland valley; RS: rainy season; DS: dry season.

**Table 4.** Characteristics of types of inland valleys.

| Characteristics | Inland valleys cultivated both in rainy season and dry season | | | Inland valleys cultivated only in rainy season | | |
|---|---|---|---|---|---|---|
| | Type 1 | Type 2 | Type 3 | Type 4 | Type 5 | Type 6 |
| Weights (%) | 12 | 23 | 9 | 11 | 19 | 26 |
| Crop in rainy season | Maize | Maize | Maize | Rice | Maize | Maize |
| Crop in dry season | Tomato, pepper | Tomato, pepper, maize | Maize/okra | no crop | no crop | no crop |
| Gross income in rainy season (FCFA/ha) | > 600000 | 100000-300000 | > 300000 | > 900000 | > 400000 | < 100000 |
| Gross income in dry season (FCFA/ha) | > 600000 | > 400000 | < 100000 | 0 | 0 | 0 |
| Soil fertility | Very good | Bad | Good | Bad | Good | Bad |
| Use of fertilizers | Yes | Yes | Yes | Yes | No | Yes |
| Technical support | Yes | No | Yes | Yes | No | No |
| Water control | Bad | Bad | Bad | Medium | Bad | Bad |

## Classification of inland valleys

The analysis of the dendrogram revealed a first level of classification of inland valleys into two groups mainly differentiated by the agricultural use (presence or absence of off season crop). In order to gain in consistency, we represented the diversity of the inland valleys by a partition into six types. Table 4 presented the characteristics of the different types of inland valleys.

### *Group 1: Inland valleys cultivated during rainy and dry seasons*

**Type 1 - Inland valleys cultivated with maize during the rainy season and with tomato and pepper during the dry season:** This type comprised 12% of the inland valleys of the study area; that is 19 inland valleys. It represented the type of inland valleys cultivated on their fringes with maize during the rainy season and in their center with tomato and pepper during the dry season with high economic productivity (greater than 600,000 FCFA/ha). These inland valleys were fertile. The producers used chemical fertilizers to maintain a high level of production. About 70% of the producers of this inland valleys group benefited from NGOs and projects supports.

**Type 2 - Inland valleys cultivated with maize during the rainy season and with tomato, pepper associated with maize during the dry season, without technical support:** This type comprised 23% of the inland valleys of the study area; that is 36 inland valleys. It represented the type of inland valleys cultivated on their fringes with maize during the rainy season and in their center with tomato and pepper associated with maize during the dry season. During the rainy season, maize cultivation generated a relatively moderate gross income (100,000 to 300,000 FCFA/ha). During the dry season, tomato and pepper associated with maize generated a relatively high gross income (over 400,000 FCFA/ha). The producers did not benefit from technical support. They usually used chemical fertilizers to produce on their inland valleys largely dominated by poor soils.

**Type 3 - Inland valleys cultivated with maize during the rainy season and with maize associated to okra during the dry season:** This type included 9% of the inland valleys of the study area; that is 15 inland valleys. It represented the type of inland valleys cultivated on their fringes with maize during the rainy season and in their center with maize associated with okra during the dry season. During the rainy season, maize cultivation generated a relatively high gross income (over 300,000 FCFA/ha). During the dry season, maize associated with okra generated a relatively low gross income (less than 100,000 FCFA/ha). The producers generally benefited from NGOs and projects support. They used chemical fertilizers to produce on their inland valleys with good soil fertility.

### *Group 2: Inland valleys cultivated only during the rainy season*

**Type 4 - Inland valleys cultivated only during the rainy season with rice:** This type comprised 11% of the inland valleys of the study area; that is 17 inland valleys. It represented the type of inland valleys cultivated only during the rainy season in rice with high economic productivity (greater than 900,000 FCFA/ha). The producers benefited from NGOs and projects support. They used chemical fertilizers to have a good production on their inland valleys dominated by poor soil fertility.

**Type 5 - Inland valleys cultivated only during the rainy season in maize with relatively high economic productivity:** This type comprised 19% of the inland valleys of the study area; that is 30 inland valleys. It represented the type of inland valleys cultivated only during the rainy season on their fringes with maize with a relatively high economic productivity (greater than

**Table 5.** Gross margin of the main crops of inland valleys (campaign 2009-2010).

| Period | Crop | Frequency (158 IV) | Yields (T/ha) | Production value (FCFA/kg) | Gross product/ha (K FCFA/ha) |
|---|---|---|---|---|---|
| RS | Rice | 37 | 3.2 (1 – 5) | 225 (150 – 350) | 500 (100 – 1500) |
| | Maize | 86 | 1.4 (0.3 – 3) | 170 (125 – 275) | 322 (30 – 800) |
| | Tomato | 64 | 2.7 (1.2-7) | 115 (100-240) | 375 (12-800) |
| | Pepper | 61 | 0.5 (0.1-1.2) | 137 (100-400) | 100 (20-270) |
| DS | Tomato | 24 | 2.9 (0.7 – 9) | 335 (250 – 350) | 1006 (100 – 3000) |
| | Pepper | 25 | 4.2 (0.12 – 10) | 460 (250 – 500) | 1017 (30 – 3500) |
| | Okra | 18 | 1.11 (0.9 – 2) | 260 (200 – 350) | 606 (105 – 1600) |
| | Maize | 4 | 2.15 (0.8-4) | 140 (100-350) | 490 (250-600) |

IV: Inland valley; RS: rainy season; DS: dry season; K FCFA: 1000 FCFA; () = class of value in 95% threshold.

300,000 FCFA/ha). The producers did not benefit from NGOs and projects support. They did not use chemical fertilizers despite the low soil fertility of their inland valleys.

**Type 6 - Inland valleys cultivated only during the rainy season with maize or vegetable with a relatively low economic productivity:** This type comprised 26% of the inland valleys of the study area; that is 41 inland valleys. It represented the type of inland valleys mainly cultivated during the rainy season on their fringes with maize or vegetable with a relatively low economic productivity. The producers did not benefit from NGOs and projects support. They used chemical fertilizers to produce on their inland valleys with relatively poor fertility.

### Factors affecting the economic productivity of inland valleys

The analysis of the gross income per unit land in the inland valleys (Table 5) showed that tomato and pepper, the major crops of off-season were distinguished by a very high gross income. The relative importance of off-season crops was therefore important in the economic productivity of inland valleys. The types of inland valleys with large presence of off-season crops (Types 1 and 2) had the highest gross income. During the rainy season, rice production generated the highest gross income. This contributed to explain the relatively high gross income in the rainy season of producers of inland valleys of type 4. Therefore, the cropping system based on rainfed rice and off-season vegetable production would be the most profitable and should be integrated in the recommendation scheme for inland valleys farmers.

## DISCUSSION

Technical support by the development institutions (projects and NGOs) to the agricultural valorization of inland valleys was a determining factor in the improvement of the gross income both in wet and dry seasons. These institutions follow, support and advise farmers and facilitate access to agricultural inputs; thereby improving farmers' technical abilities and contributing to an increase in production. Meanwhile, inland valleys whose farmers did not benefit from institutional support had a relatively lower productivity. The same observation was made by Gruber et al. (2009) and Giertz et al. (2012) about the inland valleys of central and northern Benin and by Nwaru and Iheke (2010) about the inland valleys of Abia State in Nigeria. Those authors attributed the low valorization of the agricultural potential of inland valleys to the low technical abilities of farmers and emphasized on the importance to strengthen farmers' technical abilities.

The physical environment was not an important factor in the differentiation of the inland valleys in the study area. This could be attributed to the fact that all the inventoried inland valleys presented similar soil characteristics. Contrary to our results, Karimou et al. (2005) found significant differences in the soil characteristics of inland valleys in the department of Mainé-Soroa, Niger. Furthermore, the inland valleys in the study area were not different from hydrological point of view. They were flooded from June for a period of 3 to 6 months. Their hydrological functioning was determined by the characteristics of rainfall (intensity and frequency) and the regime (flood, recession) of the Mono and Couffo rivers (Amoussou, 2010).

In the rainy season, maize was the main crop in 89% of the inventoried inland valleys and was grown on the fringes of inland valleys. Rice was the main crop in 11% of inland valleys and was grown in the center (bottom) of inland valleys. The main crop chosen by a producer during the rainy season was correlated with his ability to control the water regime in the inland valley during this season (Table 4). The inland valleys on which rice was the major crop during the rainy season were those on which the producers have a functional drainage system to prevent prolonged inundation that often disrupts planting,

germination and favors weeds proliferation (Rodenburg and Johnson, 2009). In order to capitalize on their inland valleys, most producers in the study area grow maize on the fringes (well drained areas). This shift of maize from uplands to inland valleys was observed by Ogouwalé (2006) in South and Central Benin. This shift was interpreted as an endogenous adaptation strategy to climate change by producers specifically as response to the erratic character of rainfall during the rainy season (Ogouwale, 2006).

Less than 50% of the inland valleys of the study area were cropped during the dry season (Table 4), despite the relatively high gross income from the production of off-season vegetable (Table 5). The main constraint to farming in the dry season was the lack of water to irrigate crops. Therefore, support to producers in the development of irrigation infrastructures in the dry season and drainage infrastructures in the rainy season are crucial for the diversification (rainfed rice and off-season vegetable) in inland valleys, which further determined the economic productivity (Table 5). Similar suggestions were made by Saidou and Kossou (2009) and by Totin et al. (2012) for the agricultural development of inland valleys.

## Conclusion

This study allowed understanding the diversity of inland valleys and the factors affecting their economic productivity in the departments of Mono and Couffo. Six types of inland valleys were identified based on the production system, socio-economic environment and economic productivity. The production system based on rainfed rice and off-season vegetable production with an application of chemical fertilizer generated the highest economic productivity and should be integrated in the recommendation scheme for inland valleys farmers. Furthermore, the results highlighted the importance to strengthen farmers' technical abilities for a better capitalization on inland valleys. These results support the importance of combining several approaches in the classification of inland valleys and fully understand the factors affecting their valorization by rural populations.

## Conflict of Interests

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENTS

This research was conducted in the framework of the project "Realizing the agricultural potential of the inland valley lowlands in sub-Saharan Africa while maintaining their environmental services" (RAP-IV) funded by the European Union.

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