

## USE AND CONSTRAINTS ON THE USE OF INLAND VALLEY ECOSYSTEMS IN CENTRAL BENIN: RESULTS FROM AN INLAND VALLEY SURVEY

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With 8 figures and 2 tables

Received 20 March 2012 · Accepted 05. September 2012

**Summary:** This paper assesses the current use and constraints on the use of inland valleys in central Benin are assessed to analyse their agro-potential. The methodology applied in this study is comprised of a survey of local authorities and inland valley users conducted with standardised questionnaires and the mapping of inland valley surfaces with GPS. The questionnaire contains questions to socio-economic aspects such as access to an inland valley, land tenure, current use, use constraints as well as questions to physical properties such as soil quality. In addition to the assessment of the inland valley surface area, this approach enabled a detailed socio-economic and rough physical characterization of all detected inland valleys. In total, 817 inland valleys were surveyed in this study. The local population currently uses sixty-seven percent of the valleys, primarily for crop cultivation. In most cases, only a small part of each surveyed inland valley is used. The intensity of exploitation varies across communes and across seasons. Especially in the more densely populated communes of Djougou and Parakou, where the upland soils are often degraded and arable land has become scarce in recent years, the use of inland valleys is greater than in less populated communes. This exploitation occurs primarily during the rainy season, and only a few farmers cultivate crops during the dry season. This study revealed high unused agro-potential in the inland valleys of central Benin. The main reason why inland valleys in the study area currently remain unexploited is a lack of experience in cultivating wetland. In fact, for more than 60% of the unused inland valleys, the local farmers claim to have no knowledge of which crops are adapted to seasonally waterlogged and swampy land or how to cultivate such crops. Due to climate change and population growth, the agricultural use of inland valleys in this region could become more important in the future. To ensure effective use, farmers should be supported by the regional agricultural organisation CeRPA (Centres Régionaux pour la Promotion Agricole) or development organisations to improve the knowledge of cultivation methods and inland valley management.

**Zusammenfassung:** In diesem Artikel werden die aktuelle Nutzung und die Probleme der Nutzung von Flachmuldentälern (inland valleys) in Zentralbenin basierend auf einer standardisierten Befragung der lokalen Bevölkerung und einer GPS-Kartierung analysiert. Der Fragebogen enthält sowohl Fragen zu sozio-ökonomischen Aspekten wie Zugang zum inland valley, Landrechten, aktuelle Nutzung, Probleme der Nutzung etc. als auch Fragen zu physischen Eigenschaften wie z.B. Bodenqualität. Mit diesem Ansatz konnten neben der reinen Erfassung der inland valley Fläche auch eine umfassende sozio-ökonomische und eine grobe physische Charakterisierung aller erfassten inland valleys erfolgen. Insgesamt wurden 817 inland valleys in dieser Studie untersucht. 67% dieser Feuchtgebiete werden aktuell von der Bevölkerung für den Ackerbau genutzt. In den meisten inland valleys wird nur ein kleiner Flächenanteil agrarisch genutzt. Die Nutzungsintensität variiert je nach Kommune in der Regen- und Trockenzeit. Vor allem in den sehr dicht besiedelten Kommunen Parakou und Djougou, wo die Böden der Hochländer meist degradiert sind und nutzbares Land knapp geworden ist, ist die Nutzungsrate der inland valleys höher als in den dünnbesiedelten Kommunen. Die Ackernutzung wird hauptsächlich in der Regenzeit durchgeführt, während nur wenige Bauern die inland valleys in der Trockenzeit für den Ackerbau nutzen. Die Studie zeigt, dass im Untersuchungsgebiet ein hohes agrarisches Nutzungspotenzial von inland valleys existiert. Der Hauptgrund, warum inland valleys in der Untersuchungsregion ungenutzt bleiben, ist die fehlende Erfahrung bei der agrarischen Nutzung von Feuchtgebieten. Über 60% aller befragten Bauern in ungenutzten inland valleys gaben an, dass sie keine Kenntnis darüber haben, welche Anbaufrüchte an die periodisch überschwemmten inland valleys angepasst sind und wie man sie kultiviert. Aufgrund klimatischer Veränderungen und des hohen Bevölkerungswachstums könnte die agrarische Nutzung von inland valleys in der Region an Bedeutung zunehmen. Um eine effektive Nutzung dieser Feuchtgebiete zu sichern, sollten die Bauern durch die regionalen Agrarorganisationen CeRPA (Centres Régionaux pour la Promotions Agricole) und durch die Entwicklungszusammenarbeit unterstützt werden, um das Wissen über Anbaumethoden und Management von inland valleys zu verbessern.

**Keywords:** Inland valleys, bas-fonds, wetlands, Benin, agricultural use, use constraints

## 1 Introduction

Pressure on land and soil resources due to a rapidly growing population is a severe problem across the African continent. In some regions, arable land has become scarce, and the degradation of soils continues due to the shortening of the fallow period. Furthermore, climate variability and changes in precipitation patterns in recent decades (SPETH et al. 2010) have led to growing uncertainty amongst farmers regarding the timing of cultivation and harvest. With the ongoing climate change, the availability of water is likely to decrease in the region (GIERTZ et al. 2010), which will aggravate the difficulty of rain-fed agriculture. Most farmers have little or no experience in new cultivation methods and have barely enough capital for irrigation infrastructure or drought-tolerant crops. Where soil degradation has occurred, successful agriculture requires intensified exploitation or expansion into alternative cultivation areas. Inland valleys might represent such an alternative in some areas. Inland valleys, also known as *bas-fonds* in francophone West Africa, offer extensive, relatively unexploited potential for agricultural production due to their higher water availability, lower soil fragility and higher fertility compared to upland areas. The target area of this study, the Upper Ouémé catchment in central Benin, has experienced rapid population growth in the last decade due to high fertility and high immigration rates (DOEVENSPECK 2005). This has caused the expansion of agricultural areas and led to both deforestation and shortages of land immediately available for agricultural production. Therefore, the exploitation of inland valleys could be important to the future of this region.

RAUNET (1982) defines *bas-fonds* as flat to concave valley sections and small valleys, as well as lowered drain channels, which have no distinctive stream net. The terms 'inland valley' and 'bas-fonds' are not used consistently. The term 'bas-fonds' refers to the waterlogged valley bottom and its hydromorphic fringes. In contrast, an inland valley theoretically comprises a complete toposequence from the interfluvies to the valley bottom with its seasonally waterlogged depression (WINDMEIJER and ANDRIESSE 1993). In practice, as in this article, both terms are often used synonymously and the term 'inland valley' refers only to the waterlogged area and its hydromorphic fringes (THENKABAIL and NOLTE 1996; IVC 2005). Other regional names for *bas-fonds* are 'fadamas' in Nigeria (TURNER 1985), 'bolis' in Sierra Leone (MÄCKEL 1979) or 'mare' in Senegal. In other parts of Africa *bas-fonds* are also known as 'dambo',

'mbuga' or 'vlei' (THOMAS and GOUDIE 1985). In West Africa, the total inland valley area is estimated to be approximately 22–53 million hectares (WINDMEIJER and ANDRIESSE 1993).

Throughout the African continent, and particularly in West Africa, extensive research has been performed on inland valleys. Several studies have focused on the agro-potential of inland valleys (ASSIGBÉ and MAMA 1993; GRUNERT et al. 2000; MUND and GRUNERT 1999; MUND 2004; TURNER 1986; WINDMEIJER and ANDRIESSE 1993), but also on geomorphologic aspects (e.g. RUNGE 1991). Great attention has been paid to the classification and characterization of inland valley agro-ecosystems. ANDRIESSE et al. (1994) proposed a multi-scale characterization approach with four characterization levels from macro level (agro-ecological zone), reconnaissance level (country), semi-detailed level (key area), to detailed level, which refers to the characterization of single inland valleys. A number of studies aimed at characterising inland valleys have been supported by the Inland Valley Consortium (IVC), which is a regional initiative of 10 West African countries, including Benin, and eight international research and development institutions. This consortium promotes the sustainable development of inland valleys as a means of addressing key agricultural and development concerns in sub-Saharan Africa (i.e., poverty, food security and degradation of the natural resource base).

In Benin, the *Cellule bas-fond*, a department of the *Direction de Genie Rural* (Directorate of Rural Engineering, DGR) in the Ministry of Agriculture, is the authority responsible for inland valley management. To efficiently plan and manage the exploitation of inland valleys, both the *Cellule bas-fond* and the communes need a database of information about the physical and socio-economic properties of these areas. The only such data previously available were the results of a study carried out between 1986 and 1992 by the Food and Agriculture Organization of the United Nations (FAO). In that study, approximately 180 inland valleys were identified throughout Benin (ASSIGBÉ and MAMA 1993), but these valleys were neither georeferenced nor surveyed for their physical or socio-economic properties. The previous activities of the IVC in Benin focused primarily on detailed investigations of three inland valleys in the commune of Dassa-Zoumé (ASSIGBÉ and MAMA 1993).

Even though the characterization of inland valley agro-ecosystems have been discussed since the 90s, most studies focused on the reconnaissance or the semi-detailed level using remote sensing data (e.g. THENKABAIL and NOLTE 1996; THENKABAIL and

NOLTE 2003). On the detailed level, only few studies exist and they focus on single inland valleys and mainly on a physical characterization (e.g. NARTEH et al. 2008). Why inland valleys “are only marginally used and with limited success” (ANDRIESSE et al. 1994, 159) cannot only be deduced from the physical properties of the inland valleys. It is very important to take into account socio-economic aspects, because often not physical but socio-economic constraints can hinder an efficient valley-use.

In this study, the current use and constraints on the use of inland valleys in central Benin are assessed to analyse their agro-potential. Because adequate data for this evaluation was not already available, an inventory was planned and conducted in Central Benin. In this inventory, detailed information on physical and socio-economic properties for each inland valley in the target region, was collected by interviewing local authorities and inland valley users.

This study was part of the IMPETUS project, which analysed the impact of global change on the water cycle in West Africa (SPETH et al. 2010).

## 2 Study area

This study was carried out in the communes of the Upper Ouémé catchment in central Benin (Fig. 1). The study area is located in the sub-humid Sudan-Guinea zone. Based on data from 1961–1990, the mean temperature is 26.8 °C, and the mean annual precipitation is between 1148 mm (in Parakou) and 1309 mm (in Djougou) (ERMERT and BRÜCHER 2008; FINK et al. 2008). Because the Atacora mountain chain (which is northwest of the study area) acts as an orographical barrier to the passage of the African Easterly Waves, rainfall increases from east to west. The precipitation regime is tropical unimodal, with a rainy season from April to October and a dry season from November to March (ERMERT and BRÜCHER 2008). The geomorphology is closely linked to the geologic structure of the Precambrian basement complex (Dahomeyan Series), which is composed primarily of migmatite (GIERTZ and SCHÖNBRODT 2008; EL-FAHEM and KOCHER 2008). The landscape has a slightly undulating pediplain relief at 250 to 330 m above sea level, with scattered isolated *inselbergs*. Inland valleys are typical morphological forms in the study area. These appear as flat, linear, seasonally waterlogged depressions without marked stream channels in the headwater zones (MÄCKEL 1985). Inland valleys form the primary

drainage system of the granitic and metamorphic basement complex. These valleys occur primarily on the pediplains as an intensive and deep chemical weathering over a clayey saprolitic zone. Inland valleys exhibit concave cross profiles with gently tilted slopes, flat valley bottoms and gently tilted longitudinal profiles (WINDMEIJER and ANDRIESSE 1993).

The predominant upland soils in the study area are nutrient-poor Acrisols and Lixisols (HIEPE 2008) according to the World Reference Base classification (IUSS Working Group/FAO, 2006). Deeply weathered Ferrasols are scarce. At the bottom of each inland valley, Gleysols are typical (JUNGE 2004). The predominant habitat in central Benin is dense savannah. Due to farming and slash-and-burn agriculture, most of the forest has given way to anthropogenic savannah and drastically thinned woody vegetation. Currently, natural forests occur only in scattered state reserves (Fig. 1), of which the *Forêt de l’Ouémé Supérieure* in the centre of the study area is the largest (JUDEX 2008). Land use in the study area clearly shows a north-south disparity. Anthropogenic areas predominate in the northwest around Djougou, where settlements and agricultural lands commonly stretch across paved roads. However, the agricultural use of the hitherto unused fertile savannahs in the southwest has increased due to expansion of the road network and intrarural population dynamics since the 1990s (DOEVENSPECK 2005). The most densely populated area of the study region is the commune of Parakou, which is the provincial capital (300 to 400 inhabitants per km<sup>2</sup>). Population density in the other communes is lower than 70 inhabitants per km<sup>2</sup> (HELDMANN and DOEVENSPECK 2008). Most of the population belongs to the ethnic groups of the Bariba, Lokpa, Yom, Yoruba and Yoruba related groups (Nagots) (HELDMANN 2008). Another important ethnic group in the study region is the pastoral Fulani, who immigrated from Sahel and northern Benin (DOEVENSPECK 2005). Subsistence farming is the predominant form of agriculture in the region. In shifting cultivation, farmers mainly produce maize (*Zea mays*), cassava (*Manihot esculenta*) and yams (*Dioscorea esculenta*). The typical crop rotation is yams-maize-fallow. Traditional intercrops are sorghum (*Sorghum bicolor* L.), cowpeas (*Vigna unguiculata*), chili (*Capsicum chinensis*), tomato (*Solanum lycopersicum* L.), okra (*Abelmoschus esculenta*), banana (*Musa × paradisiaca*) and cashew (*Anacardium occidentale*) (MULINDABIGWI 2005). Due to their higher water availability, inland valleys are often used for rice cultivation (*Oryza sativa*).

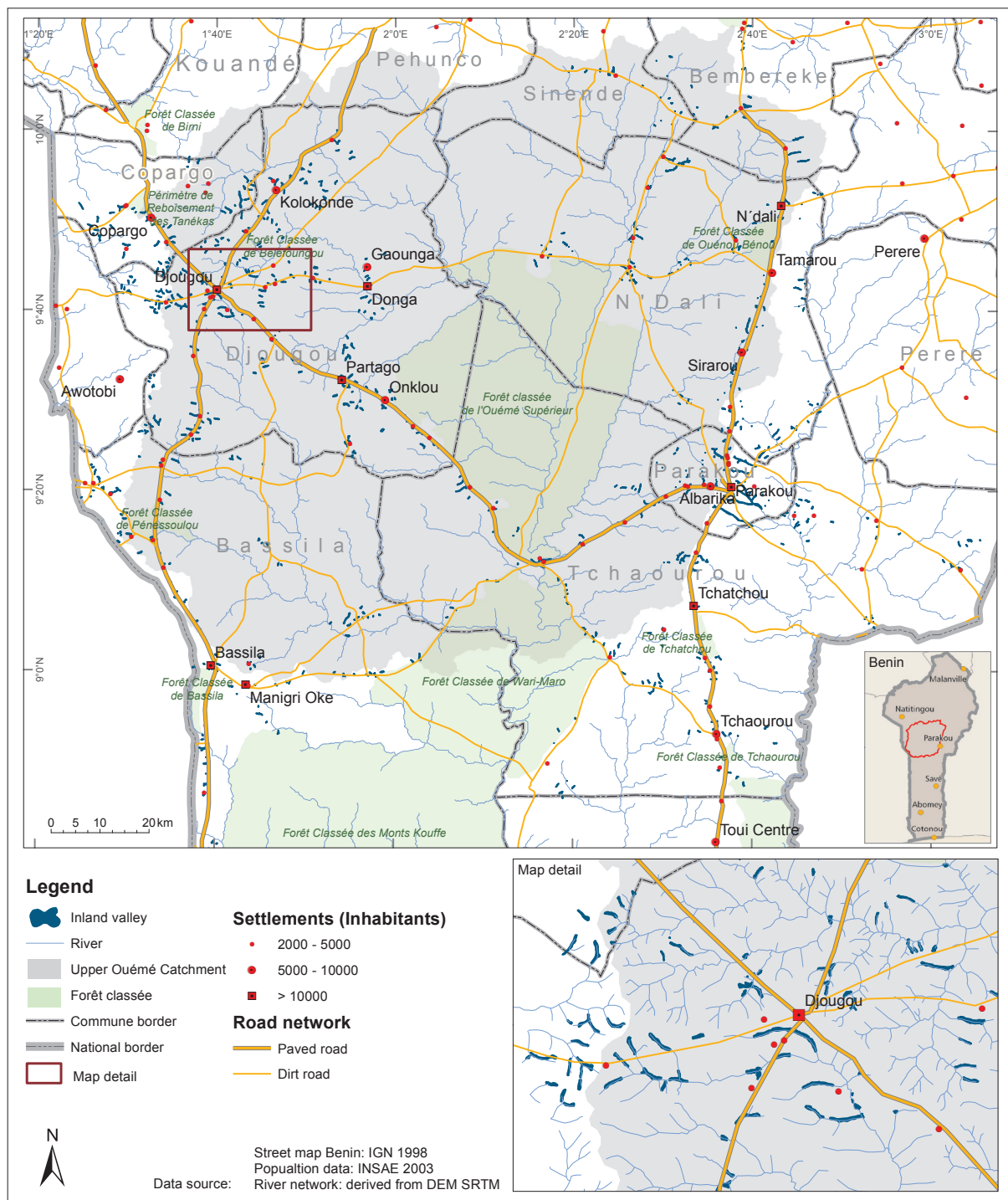


Fig. 1: Surveyed inland valleys in the Upper Ouémé catchment

### 3 Methodology

The methodology applied in this study was based on the available information about inland valley characterisation and was developed after in-

tensive discussions with the national inland valley authority of Benin (the *Cellule bas-fond*), the IVC and experts from the University of Abomey-Calavi. The discussion revealed that physical properties (e.g. size, soil quality, inundation period and height) as well

as socio-economic aspects such as access to an inland valley, land tenure, use constraints and reasons against using this particular inland valley are important to decide whether it is reasonable and sustainable to support the inland valley exploitation and the construction of water management measures.

Even though an identification of inland valleys is possible with remote sensing techniques, no detailed physical or socio-economic characterization can be carried out using solely these datasets. Therefore, an extensive field investigation was carried out to map the inland valleys of the region and to determine their physical and socio-economic properties. This investigation comprised a survey of local authorities using standardised questionnaires and the mapping of inland valley surfaces using GPS. We preferred using the manual mapping via GPS rather than a remote sensing approach based on aerial photographs due to the greater accuracy of this approach and a lack of high quality aerial photographs for the whole target area.

We developed the questionnaires in consultation with the *Cellule bas-fond*, members of the IVC and of the University of Abomey-Calavi. Before starting the survey, pre-tests were performed in three villages, and the questionnaires were subsequently adapted accordingly.

The field work was performed in cooperation with the *Cellule bas-fond*.

The communes of N'Dali, Djougou, Parakou, Bassila and Tchaourou (see Fig. 1) were surveyed in their entirety. For Copargo, Sinende and Bembéréké, only the parts of each commune lying within the Upper Ouémé catchment were taken into account. In this region, each village or city quarter listed in the national census was visited to locate all known inland valleys within the territory of each settlement.

In cooperation with local authorities (*chefs de village or délégués*), a questionnaire was filled out for each village (or quarter) to obtain information about the number of known inland valleys within the village territory, the ethnic composition of the village, the existing land use rights and other socio-economic characteristics. After the general interview with the local authorities, at least one farmer or landowner associated with each inland valley was called to complete a detailed questionnaire. This questionnaire was used to assess aspects of soil quality, hydrology, the ethnic affiliation of the farmers, the extent of exploitation of the inland valleys, management structures, the selling of products on the markets and other factors. In addition, the extent of each inland valley was mapped, with the assistance of local farmers, using

GPS. To save time, very small inland valleys (< 0.5 ha) were mapped based on one central point, and an estimate of size was made by the technical assistant. For these small inland valleys, only a short questionnaire was filled out.

Based on the GPS data, the surface of each mapped inland valley (> 0.5 ha) was calculated and the hydrologic catchment of each inland valley was determined using ArcGIS. All of the data from the field study and the GIS analysis were compiled in a database, which was provided to the *Cellule bas-fond* to support its inland valley management efforts.

## 4 Results

In total, 817 inland valleys with a total surface area of 5,563 ha were identified in the research area. Figure 1 shows the locations of all surveyed inland valleys. As shown in the figure, most of these valleys were located near roads, and no inland valleys were mapped in remote areas or in protected forests. This is a consequence of the methodology used, which focused on villages as the starting points for the field survey. Small settlements in the savannah often do not have the legal status of official villages. Therefore, they do not appear in the national census data, and inland valleys within their territory were not included in this survey.

### 4.1 Physical characterisation

Data from the generated database and the additional GIS analyses were used to document the morphological, hydrological and pedological properties of the surveyed inland valleys. The size distribution of the surveyed inland valleys is presented in figure 2. The majority of the inland valleys are between 1 and 10 ha, but large valleys of more than 50 ha were also detected in the research area (maximum: 135 ha). Nevertheless, more than 80% of the surveyed valleys are smaller than 10 ha, and more than 95% are smaller than 20 ha. The only inland valleys larger than 60 ha were found in the commune of Parakou. These valleys are located around the drainage network as a buffer, and they could be interpreted as several individual inland valleys in a row.

With regard to the hydrological characteristics of the inland valleys, local farmers were asked to report the normal beginning and ending dates of the inundation period for both the centre and the hydromorphic fringe of each valley. The hydromorphic fringe is a

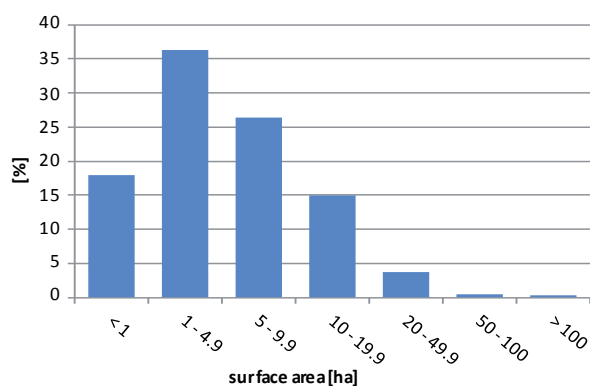


Fig. 2: Distribution of the surface areas of mapped inland valleys

strip of land 10 to 15 meters in width that surrounds the centre of each inland valley. This fringe is characterised by hydromorphic soil characteristics and a short period of inundation. In most cases, farmers reported a month for each date, and an unambiguous interpretation of such data is not possible. A period identified as beginning in August and ending in October could mean an inundation as short as one month (the end of August to the beginning of October) or as long as three months (the beginning of August to the end of October). For the analyses, we used the middle of each month, such that “August to October” means two months of inundation. In cases where the same month was given for the beginning and the end of an inundation period, that period was set to one month. The results of this analysis are shown in figure 3. Almost 90% of the inland valleys were inundated for a period of two to five months annually. The fringes were generally characterised by shorter periods of inundation. In more than 75% of the surveyed inland valleys, the inundation period started in August, in 21% it started in July, and in about 3% of the valleys, it started as early as May or June. The maximum water

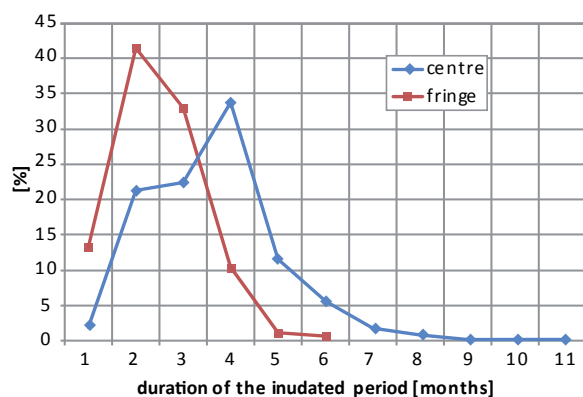


Fig. 3: Distribution of the inundation period durations at the centre and the fringes of the inland valleys

level in the centre of each inland valley varied between ten centimetres and (in two cases) more than two meters, but in 75% of the cases, it ranged between 50 centimetres and one meter.

The depth of the groundwater table in the dry season is the most important factor in determining whether inland valleys can be used for agriculture during this period. In the questionnaires, the local farmers were asked to report the depth at which water can be found in each inland valley at the end of the dry season. The local population was able to provide this information for only 35% of the inland valleys. This can be explained by the fact that most of the inland valleys are not yet used in the dry season, as was true of 82% of the inland valleys for which further information about the water table was not available. In inland valleys that are used during the dry season, there are usually hand-dug wells in which the water level can be observed so that the farmers are familiar with the local groundwater conditions. LIGHTFOOT et al. (2009) tested the reliability of interview data on groundwater levels in Uzbekistan and found that an estimation of depth to the water table can reliably be made based on oral reporting by local farmers. In the current study, the observed depth ranged between zero and six meters below the surface. In 80% of the cases, water can be found at depths of less than two meters, and in 90% of the cases, it can be found at depths of less than three meters.

To obtain a rough assessment of the agricultural potential of the inland valleys, the farmers were asked to classify the soil fertility as high, medium or low. The soil fertility was classified as high in over 90% of the cases and as low in less than 1% of the cases. Table 1 shows the evaluation of the current soil fertility for the major communes of the Upper Ouémé catchment. Whereas in the communes of Bassila and Tchaourou, all of the inland valley soils were evaluated as “good” by the farmers, inland valleys in the densely populated commune of Parakou were reported to have lower soil fertility. This can be explained by the more intensive exploitation with shorter fallow periods in Parakou.

Tab. 1: Estimates of soil quality by farmers interviewed in the major communes of the Upper Ouémé catchment [%]

Commune	High	Intermediate	Low
Bassila	100.0	0.0	0.0
Djougou	92.6	6.9	0.4
N'Dali	73.2	26.8	0.0
Parakou	60.0	28.0	12.0
Tchaourou	100.0	0.0	0.0

### 4.2 Use of inland valleys

Of the total 817 surveyed inland valleys, 548 are currently used by the local population, primarily (86%) for crop cultivation. However, in many cases, only small patches of the inland valleys are used. Other uses, such as pisciculture, fishing, animal husbandry and the collection of firewood, are of minor importance. In the following section, only agricultural use is analysed.

Figure 4 shows the total area of cultivated land during the rainy and dry seasons in the inland valleys of each commune. As this figure indicates, the intensity of exploitation varies across communes and across seasons. The use of inland valleys is particularly high in the more densely populated communes of Djougou and Parakou, where the upland soils are often degraded and land has become scarce in recent years. In other communes that are more sparsely populated (such as Bassila and Tchaourou), the exploitation of inland valleys is less intense.

Further analysis of the total cultivated area revealed that inland valleys are cultivated primarily during the rainy season, and only a few farmers cultivate such land during the dry season. In the more densely populated communes, the exploitation rate during the rainy season exceeds 60%, whereas in the

communes of Bassila and Tchaourou in the southern part of the study area, less than 20% of the inland valley surface area is exploited during the rainy season. In the dry season, most of the inland valleys are not cultivated. Even in the communes that are experiencing land degradation and land scarcity problems, the exploitation rate is less than 20% during the dry season. Therefore, an expansion of the area under cultivation in the surveyed inland valleys is possible, primarily during the dry season.

### 4.3 Cultivated crops

Through the questionnaires, the crops cultivated in each surveyed inland valley were ascertained. The farmers reported the crops cultivated during the rainy and dry seasons as well as the principal crop cultivated in each inland valley. As shown in figure 5, rice is the principal crop in 62% of the cultivated inland valleys. Other important crops are yams and maize. The latter two crops are cultivated not in the central part of each inland valley, which is inundated during the rainy season, but at the sandy fringes. Whereas these crops are cultivated only using rain-fed agriculture during the rainy season, other crops, such as tomatoes, chili and okra,

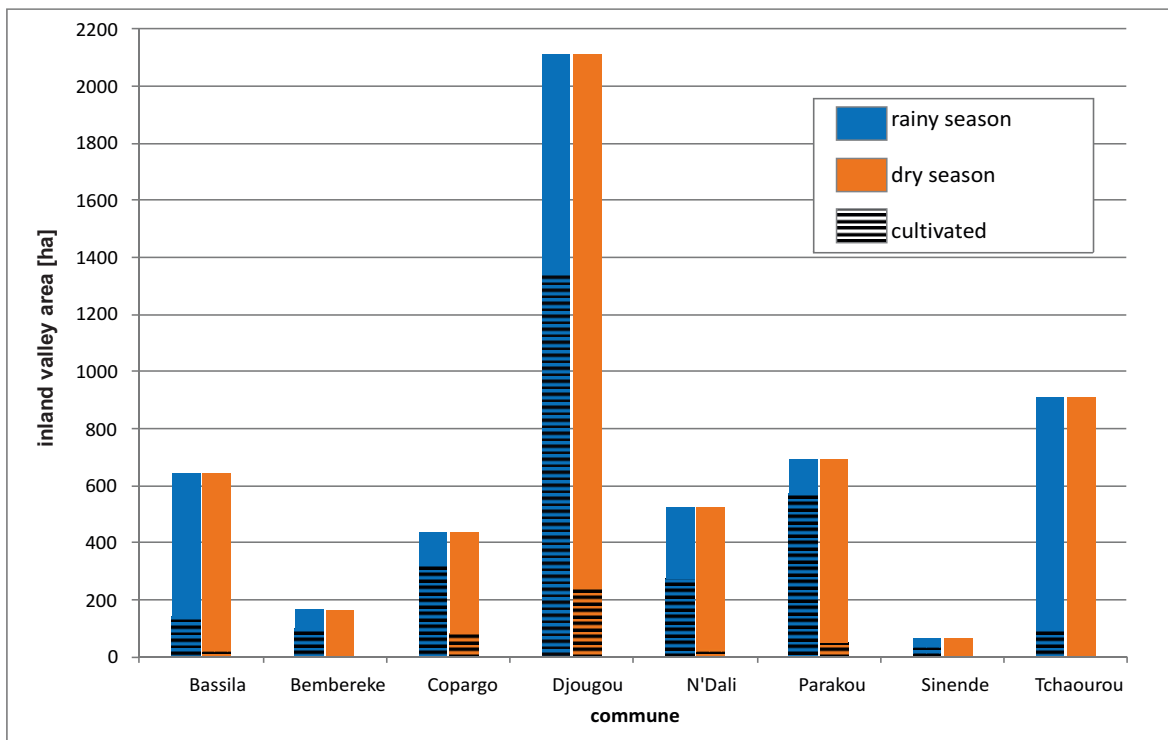


Fig. 4: Total inland valley surface area and cultivated inland valley surface area mapped in each commune of the Upper Ouémé catchment

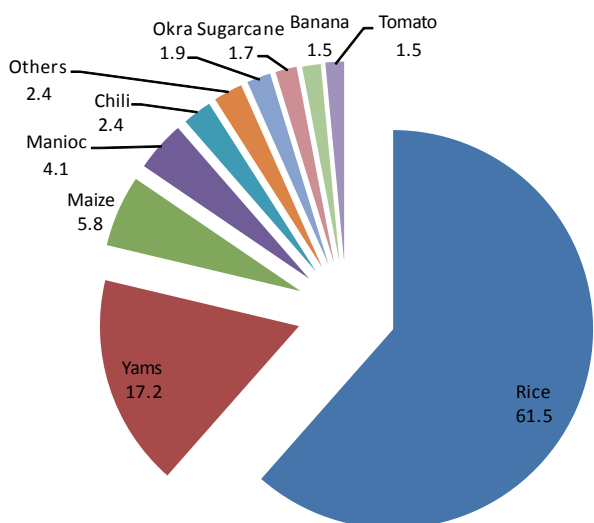


Fig. 5: Primary crops cultivated in the surveyed inland valleys [%]

are cultivated primarily using irrigated agriculture during the dry season. Only a very few farmers use technical support such as motor pumps for irrigation. Most of the irrigation is carried out manually using a ewer or calabashes and water from hand-dug wells that reach the shallow groundwater table in the inland valleys.

As mentioned in Section 2, the ethnic composition of Benin is highly diverse. In the study area, more than 46 different ethnic groups were identified as users of the inland valleys included in the survey (Fig. 6). Not all of these ethnic groups have

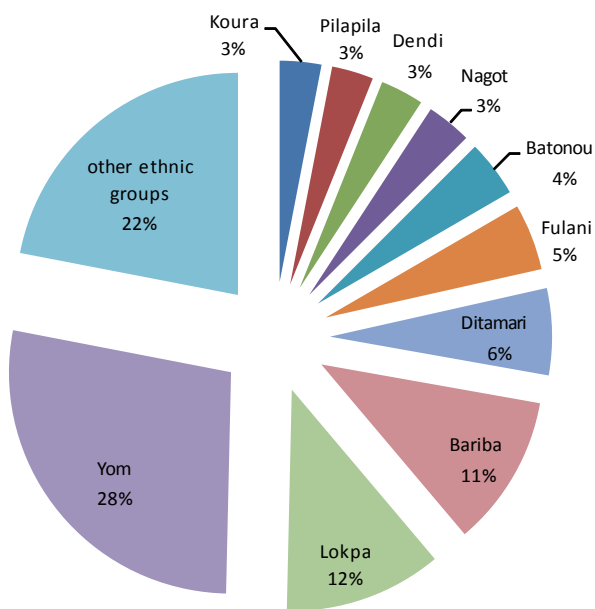


Fig. 6: Ethnic groups exploiting inland valleys in the research area

traditionally used inland valleys for agriculture. For example, the Nagots, who live primarily in the communes of Bassila and Tchaourou, traditionally have not used inland valleys for agriculture. This partially explains the low rate of inland valley exploitation in these communes. Approximately 28% of the used inland valleys are exploited in part by the Yom, who constitute the major ethnic group in the commune of Djougou. Another important group using inland valleys in north and central Benin are the Bariba, who live primarily in the communes of N'Dali, Parakou, Tchaourou and Sinende. Other ethnic groups that use inland valleys are the Lokpa, Ditamari and Peulh (Fulbe). The remaining ethnic groups identified in the survey use less than five percent of the surveyed inland valleys.

As each ethnic group traditionally cultivates distinct crops, the crop mix was analysed separately for each of the two principal user groups (Yom and Bariba; Fig. 7). Only those inland valleys that are used solely by either the Bariba or the Yom were taken into account. This analysis considered only how often a crop was reported as the main crop cultivated rather than the proportion of the cultivated area devoted to a particular crop. Rice is the dominant crop of the Bariba and constitutes the principal crop in 70% of the cases. For the Yom, rice is the principal crop in 46% of the cases, and maize and cassava are additional important crops.

#### 4.3 Constraints on use

To understand the current constraints on the cultivation of inland valleys, local farmers were asked to specify the difficulties that they face in cultivating such areas or their reasons for not doing so. Specifically, for unexploited inland valleys, farmers were asked: "Why is the inland valley not cultivated?" For inland valleys in which cultivation occurred, farmers were asked: "What difficulties in inland valley cultivation exist?" Due to the open-ended nature of these questions, the interviewed farmers often stated more than one reason or problem. The analyses of the results takes into account all of these statements.

The main difficulties that farmers face when cultivating inland valleys are invasions by animals, parasites and weeds. Birds and small rodents in particular damage crops. As shown in table 2, problems with animals, parasites and weeds represent almost 60% of the statements made by farmers concerning the difficulties of cultivation in inland valleys. However,



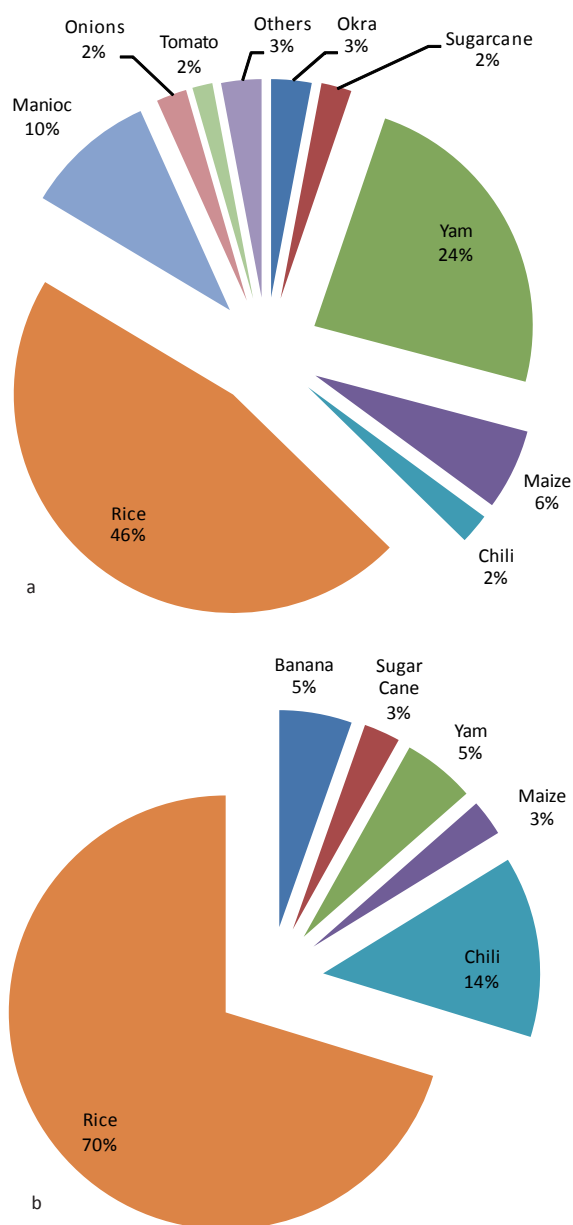


Fig. 7: Primary crops of the Yom (a) and the Bariba (b) in the surveyed inland valleys. Only those inland valleys that are used solely by either the Bariba (37 inland valleys) or the Yom (134 inland valleys) were taken into account.

these problems are not specific to inland valleys; they also exist in other farming systems. Further important constraints on the cultivation of inland valleys are imposed by water management problems (which were mentioned in 24.6% of all statements). In particular, the lack of irrigation water during the dry season is a major problem for many farmers. Irrigation in the dry season requires either a well to access groundwater or a dam to retain water from

the rainy season. If no water management structures exist, dry season irrigation is very difficult. Often, farmers use hand-dug wells to access groundwater, which is close to the surface in the inland valleys. At the end of the dry season, these shallow wells often dry out. The control of inundation during the rainy season is also difficult. Therefore, many farmers desire the establishment of water management structures through development projects by the *Cellule bas-fond*. Other difficulties mentioned by farmers during the interviews include soil cultivation problems, especially due to the high clay content of the soils (“heavy soils”), and a lack of tools for cultivating the soil.

The main reason why inland valleys in the study area currently remain unexploited is a lack of experience in the cultivation of such land (Fig. 8). For more than 60% of the unused inland valleys, farmers reported having no knowledge of which crops are adapted to these seasonally waterlogged and swampy areas or how to cultivate such crops. Nearly 12% of the farmers reported avoiding inland valley cultivation due to infrastructural problems including a lack of either the manpower required for cultivating or the financial capital required for buying seeds and equipment. An additional reason given was the poor accessibility of many inland valleys. For 2% of the unused inland valleys, the scarcity of water during the dry season was an important factor. Farmers also claimed that the uncertain and unpredictable start of the rainy season hinders cultivation. Problems with soil cultivation due to crusted or heavy soils, low soil fertility and insufficient area for cultivation are also reasons reported by farmers for avoiding inland valley cultivation. Other reasons given include the location of some of the inland valleys within state forest reserves (Forêt Classé de Wari Maro and Forêt Classé de l’Ouémé Supérieur), restrictions imposed by village authorities, religious reasons (some of the sites are considered holy places) and impending support from the *Cellule bas-fond* or impending development projects.

## 5 Discussion

### 5.1 Discussion of the methodology

The methodology applied in our study combines a survey of local authorities and inland valley users with a mapping of inland valley surfaces based on GPS measurements. Through the use of remote sensing data, the identification of wetlands is

**Tab. 2: Problems faced in the cultivation of crops in inland valleys (according to statements made by farmers approximately 374 inland valleys >0.5 ha each)**

Problems in inland valley cultivation	% of all statements
Invasion by animals (birds, rodents)	29.66
Problems with parasites or weeds	29.10
Water management problems	24.63
Problems with soil cultivation	8.58
Lack of cultivation equipment	4.66
Lack of knowledge, experience or training	2.05
Other problems	1.31

possible without extensive fieldwork. SAKANÉ et al. (2011) used different types of remote sensing data (aerial photographs, ASTER and Landsat satellite images) to identify wetlands in East Africa. RUNGE (1991) mapped inland valleys in Togo through the stereoscopic analysis of aerial photographs. If aerial photographs are available in a good quality, the GPS-mapping can be substituted by using this data. For the evaluation of the agro-potential, physical and socio-economic data are needed, which cannot be gained from remote sensing data. To obtain this information field investigations are required. In this study the physical characterization of the inland valleys was based on statements of the interview partner and an assessment of the technician of the inland valley authority. Of course, this method can give only a rough estimation of the physical properties, which have to be completed through measurements if more detailed information is needed. Despite this, LIGHTFOOT et al. (2009) showed that farmers can give reliable information on physical properties of their land. This was also confirmed in the studies of JUNGE (2004), who worked together with farmers within the IMPETUS project. Due to financial and time constraints, a detailed physical characterization based on measurements cannot be carried out for all inland valleys in any given country or key area. ANDRIESSE et al (1994) proposed in his paper to select one or two inland valleys for the physical characterization. This was also done by the IVC in Benin, but the results for one or two inland valleys cannot be transferred to other sites. Accordingly, the results have limited application possibilities in the evaluation of the agro-potential and for planning purposes. The interview-based method is therefore an alternative in which relevant informa-

tion on physical properties is gained for each inland valley. With this method it is, for example, possible to distinguish between inland valleys with good and bad soil quality. In our study, bad soil quality was found mainly in inland valleys, which had been used for several decades (e.g. in the city of Parakou).

Often, not the physical but socio-economic constraints hinder effective use and management of inland valleys. Many of socio-economic details cannot be assessed using solely secondary or remote sensing data. This data can differ significantly from village to village and from inland valley to inland valley due to ethnic differences, gender of the user etc. These details are of major importance for the planner in order to be able to decide whether exploitation of an inland valley is reasonable and worth being supported.

Of course, the quality of the data strongly depends on the interviewer, the available interview partner in the village and his willingness to give detailed and truthful information.

## 5.2 Discussion of the results

A total of 817 inland valleys with a total area of 5,563 ha were identified in the research area. The actual total area covered by inland valleys is much higher because inland valleys not known to the local population were not taken into account in this study. In particular, inland valleys in remote areas or within protected forests were not mapped. However, these inland valleys are not of major interest for potential agricultural use. A rough estimate of 133,500 ha for the total area of inland valleys within the study region (including

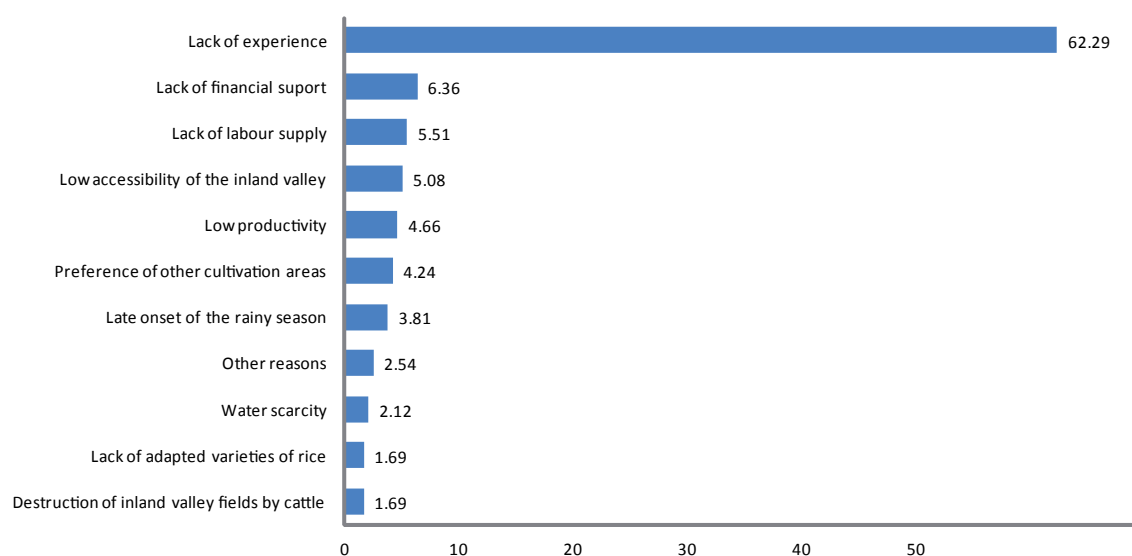


Fig. 8: Reasons given by farmers for avoiding cultivation of inland valleys (in statements concerning 222 unused inland valleys > 0.5 ha each)

valleys in remote areas and protected forests) was derived by the IMPETUS project (IMPETUS 2007) using GIS analysis of a digital elevation model in combination with remote sensing data. The total area of inland valleys across Benin is estimated to be between 160,000 ha (ASSIGBÉ and MAMA 1993) and 205,000 ha (SINGBO and LANSINK 2010). Within the surveyed inland valleys, the potentially arable land area is much higher than the area that is currently used by the population. The area of unused land in the inland valleys is especially high in the dry season. Even in the densely populated region of Djougou, where soil degradation and a scarcity of fertile arable land are already severe problems (HIEPE 2008; MULINDABIGWI 2005), the agricultural use of inland valleys is relatively uncommon. The main reason for this is a lack of experience. Training by the regional agricultural organisations (CeRPA) or development projects could improve the knowledge of the local farmers about methods for cultivation in inland valleys. Especially in regions with ethnic groups, which are traditionally not using inland valleys (e.g. Nagot in the commune Bassila), training farmers could be very useful to promote inland valley utilisation. Most studies of inland valley soil quality report that these lowland soils exhibit favourable properties compared to upland soils in West Africa (OGBAN and BABALOLA 2003). The fertility of the soil varies depending on the ecological zone. ISSAKA et al. (1997) reported that soil fertility parameters are generally low in the Guinea savannah zone, whereas in dryer regions

such as the Sudan and Sahel savannah zones, fertility is generally higher. In general, all West African lowland soils have lower values of general fertility parameters and poorer mineralogical characteristics than paddy soil in tropical Asia (ABE et al. 2010). In this study, no laboratory analyses were conducted of soil quality parameters such as nitrogen content or effective cation exchange capacity. However, the rough estimate of soil quality by the farmers indicated that most of the soils in the inland valleys considered here are of good quality. Only in densely populated regions, where inland valleys were used more intensively and over a longer period, was the quality estimated as moderate or low.

Another advantage of inland valley soils as compared to upland soils is the extended water availability. In inland valleys, the period during which sufficient water is available for plants is approximately 1–2 months longer than that of upland soils. In a study by GIERTZ (2004), soil moisture measurements with TDR probes on a transect in the Aguima catchment (Bassila commune) indicated that at the end of November, when upland soils had dried to a residual water content of less than 6%, the water content at the fringe of the inland valleys was still 33%.

Agricultural production in inland valley bottoms also has constraints that must be taken into account. OGBAN and BABALOLA (2003) stated that the most important constraint on crop production in inland valleys is the small size of these areas. Most of the inland valleys considered in that study

are less than 1 ha in area and, consequently, are suitable only for small-scale subsistence farming. In our study area, as shown in figure 2, very large inland valleys can also be found. The mean surface area of the inland valleys surveyed in our study is 6.8 ha.

The most important constraints on inland valley farming reported by the farmers interviewed in this study are problems with weeds, animals and parasites. These are common problems in all tropical agro-ecosystems, not only in inland valleys. Weeds are especially likely to be the limiting factor for yields, particularly in moist valley bottoms (OGBAN and BABALOLA 2003). This was confirmed by JAMIN and ANDRIESSE (1993) for inland valleys across seven countries in West Africa (Benin, Burkina Faso, Ivory Coast, Ghana, Mali, Nigeria and Sierra Leone). Weed control, which is performed manually using cutlasses and short-handled hoes, can take 50% of the time spent by farmers in the field in the humid tropics (OGBAN and BABALOLA 2003). High weed pressure has a strong negative effect on crop yields. A study by BECKER and JOHNSON (2001) in an inland valley in Ivory Coast found a significant negative correlation between weed biomass and rice grain yield. BECKER et al. (2003) reported that water control through bunding reduced weed biomass and substantially increased the yield of rice crops. A study by TOURÉ et al. (2009) in an inland valley of Ivory Coast showed that installing field bunds increased yields by 30–40% and lowered cumulative weed biomass by 25%. These studies illustrate the importance of water management in inland valleys used for agriculture. Problems with water management were reported as important constraints on the use of inland valleys in our study area (24.6% of all statements). The national inland valley authority, the *Cellule bas-fond*, supports farmers in building up water control infrastructure. Development organisations often finance these projects, as almost no budget is provided by the government for this purpose. The support of the *Cellule bas-fond* has thus far been limited to a few projects in selected inland valleys, e.g., in Dakparou, Komigea and Gomaezparou in the commune of Parakou. In the inland valley of Dakparou, for example, retention bunds (*diguettes de retention*) of 30–50 cm were built along contour lines to retain water. A sluice ensures water control in the case of high water levels. Within these larger retention bunds, smaller bunds for each parcel of 20 x 20 m (*diguettes de parcelles*) were built. In other inland valleys, the *Cellule bas-fond* has installed irrigation systems with wells and motor pumps to facilitate irrigation during the dry season.

## 6 Conclusions and outlook

This study aimed to analyse the actual use, constraints on the use and the agro-potential of inland valleys in central Benin. The study revealed high, unused agro-potential in these valleys, especially during the dry season and in regions with ethnic groups, which are traditionally not using inland valleys. With the interview-based method, it was possible to get detailed information on socio-economic properties and a rough assessment of physical properties like soil quality, inundation period etc. for each inland valley in the target area.

In the future, the agricultural use of inland valleys could become more important in central Benin due to the consequences of population growth and climate change. The latter is predicted to have a major impact on the availability of water (GIERTZ et al. 2010) and, consequently, on agricultural production. Many farmers in central Benin already suffer from the shortening of the rainy season, which might become more severe in the future. The reduced rainfall and higher temperatures will lower the soil moisture and consequently the water available for plants. In inland valleys, the period with sufficient water availability for non-irrigated cultivation is longer.

To ensure effective use, farmers should be supported by the regional agricultural organisation CeRPA (Centres Régionaux pour la Promotion Agricole) or development organisations to improve the knowledge of cultivation methods and inland valley management.

JUNK (2002) stated that despite the importance of a sustainable management of wetlands, detailed wetland inventories are missing in most countries. He is aiming towards a close cooperation between scientists, local decision makers, wetland managers and people living in the respective wetlands. In this application oriented study we have shown that a close cooperation between scientists and stakeholders can provide mutually valuable data. Due to the data's importance for national planning concerning inland valley utilisation, we provided our database to the national inland valley authority, the *Cellule bas-fond*. However, as a result of the decentralisation process in Benin, the communes themselves are responsible for land use planning. The information about inland valley use is therefore also of major interest for those communes. Because the administrative staff at the commune level is usually not accustomed to working with databanks, the data from this study were compiled into the information system BenIVIS, which has a graphical user interface and visualisation tools

(IMPETUS 2009). This information system was developed in cooperation with the *Cellule bas-fond*.

The *Cellule bas-fond* and the IVC aim to carry out similar investigations for the entire country of Benin and to complete the BenIVIS database. Until today the survey have been carried out for the Zou and the Mono catchment by the *Cellule bas-fond* and the national water authority, DGEau. The staff of the *Cellule bas-fond* and the DGEau was trained during the IMPETUS joint project in how to integrate new inland valley datasets into the BenIVIS system.

### Acknowledgements

The authors would like to thank the German ministry of education and research (BMBF, grant No. 01 LW 0301A) as well as the MSWF Northrhine-Westfalia (grant No. 223-21200200) for funding the IMPETUS project within the framework of the GLOWA program. We would also like to thank the *Cellule bas-fond* and the IVC for their collaboration and especially Moussa Mamaham for his help in setting up the inland valley database. Finally, we are particularly grateful to Felix Gbaguidi and Luc Sintondji for their support in organising the inland valley survey.

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