Evaluating inland valley agro-ecosystems in Ghana using a multi-scale characterization approach

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ABSTRACT

As part of measures for improving the productive capacities of inland valley systems for rice-based cropping systems, a published multi-scale characterization approach was used in Ghana to assess the constraints and variables which must be understood before agronomic interventions are made. Macro, reconnaissance, semi-detailed and detailed levels of characterization at their respective scales were used. Between 1996 and 1999, Geographical Information System (GIS) and transect studies were carried out, after which the extent of variability in the biotic and abiotic characteristics of two agro-ecologies were identified. Ten agro-ecological units were identified for Ghana based on map overlays and cluster analysis. The method allowed for the selection of Mankran and Jolo-Kwaha watersheds representing the equatorial and savanna agro-ecologies, respectively. Socio-economic parameters (markets, population density and suchlike) were recognized as the essential variables, which should be considered alongside lithology, climate, hydrology and others, for the choice of valleys for development interventions for crop production. At the detailed level of characterization, hydrological and soil characteristics underscored the need to properly understand the watershed-level and valley-specific constraints before meaningful rice-based research and cropping systems are developed.

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RÉSUMÉ

NARTEH, L. T., MOUSSA, M., OTOO, E., ANDAH, W. E. I. & ASUBONTENG, K. O.: *Evaluation d'agroécosystèmes de vallée de l'intérieur du Ghana en utilisant l'approche de caractérisation multiéchelle.* En tant que partie de mesures pour améliorer les capacités productives de systémes de vallée de l'intérieur pour les systèmes de culture basés sur le riz, une approche de caractérisation multiéchelle publiée était employée au Ghana en vue d'estimer les contraintes et les variables qu'il faut comprendre avant que les interventions agronomiques soient faites. Les niveaux macro, reconnaissance, semi-détaillé et détaillé de caractérisation à leurs échelles respectives étaient utilisés. Entre 1996 et 1999, l'étude transversale et du Système Informationnel Géographique (SIG) étaient faites à la suite de quelle l'étendue de variabilité de caractéristiques biotiques et abiotiques de deux agro-écologies étaient identifiées. Dix unités agro-écologiques étaient identifiées pour le Ghana basé sur l'analyse de revêtements et de rassemblement sur la carte. La méthode permettait la sélection de lignes de partage des eaux de Mankran et de Jolo-Kwaha représentant respectivement les agro-écologies équatoriales et savanes. Les paramètres socio-économiques (les marchés, la densité de population, etc.) étaient reconnus comme les variables essentielles, qui devraient être considéré à côté de la lithologie, le climat, la hydrologie, etc.; pour le choix de vallées pour les interventions de développement pour la production des cultures. Au niveau détaillé de caractérisation, les caractéristiques de hydrologie et de sol soulignent la nécessité de comprendre vraiment les contraintes de niveaux de lignes de partage des eaux et les contraintes spécifiques à certaines vallées avant que la recherche et les systèmes de culture utiles basés sur le riz soient développés.

Introduction

Many West African countries have sought to increase crop production and productivity by focussing on the many topographically variable inland systems. In West Africa enough water is available to irrigate large areas, but large-scale irrigation projects have not been considered as the solution for increased food production for varied reasons. The FAO (1986), for example, suggested that in cases where the need and the potential exist, irrigation may not be financially viable. Estimated area of inland valleys in West Africa (the valley bottom and their hydromorphic fringes) ranges between 22 and 52 million ha of land (Windmeijer & Andriesse, 1993). These lands are now marginally used with only 10-25 per cent of the total valley bottom area under cultivation (Andriesse *et al*., 1994). Out of the about 4.1 million ha cultivated in West Africa, 84 per cent are rainfed, and 93 per cent are in the moist savanna and humid zones (WARDA, 1995). The total area of the inland valley systems in Ghana has not been systematically analyzed, but it is estimated at about 1 million ha (Dekuku *et al.*,1993). Many development programmes with focus on rice cultivation have been put in place to realize the full potential of these otherwise marginal lands.

Inland valleys, as defined here, designate the upper parts of a river drainage system. Generally, any valley occurs inland, but the Inland Valley Consortium (IVC) has adopted the term 'inland valley' because of its widespread use in English-speaking West Africa. It refers to valleys, inland regarding the main rivers and tributaries, in which river sedimentation processes are absent or imminent only. They do not have any distinct floodplain and levee system. In French-speaking West Africa, inland valleys are best known as '*bassins versants*'. The concept of inland valley comprises the toposequence or continuum–from the uplands to the valley bottom (in French, bas-fond). The continuum is a landscape concept, which describes an environment in which a diversity of ecosystems occurs (Windmeijer & Andriesse, 1993). The upland/inland swamp continuum refers to a sequence of land types and associated ecosystems varying from upland in the higher parts, through hydromorphic conditions lower down the slopes, to swampy in the valley bottoms.

Characterization of inland valley systems is an important step toward their enhanced and sustainable use. Characterization of inland valleys has gained much interest among researchers at various international and national research institutes. Major contributors to knowledge on characterization of inland valleys have been Smaling, Dyfan & Andriesse (1985) and Izac & Tucker (1993). Andriesse & Fresco (1991) gave an overview of rice-growing environments concerning broad agro-ecological zones and inland toposequences in West Africa. Other attempts were aimed at proposing litho-morphologic (Moormann, 1981; Raunet, 1982) or morpho-hydrologic (Killian & Teissier, 1973; Moormann & van Breemen, 1978).

Reports by Phillips (1959), Papadakis (1966), Robertson (1975), Thompson (1975), Buddenhagen (1978), and Moormann & Veldkamp (1978) discussed outlines of climatic zones in tropical Africa concerning rainfed rice production. However, as pointed out by Andriesse *et al*. (1994), none of the earlier studies considered the specific conditions along the inland valley toposequences, but noted that the classification system of Bowles & Garrity (1988) dealt to some extent with some multiple aggregate levels.

In 1993, the IVC was established in West Africa to strengthen research on sustainable use of inland valley agro-ecosystems. The Consortium comprises 10 West African countries and seven international institutions. Ghana has been a member of this network since 1994. The first phase of the work of the Consortium between 1994 and 1999 emphasized a comprehensive characterization of inland valley agro-ecosystems in West Africa.

This paper presents how a multi-scale

characterization of inland valley agro-ecosystems in Ghana was used to identify constraints and opportunities for enhanced use of inland valleys.

Materials and methods

The characterization procedures as proposed by Van Duivenbooden & Windmeijer (1995) were followed (Table 1). Work on the macro level characterization started in 1994. At the reconnaissance level of characterization, GIS tools were used when the maps were digitised and overlays were prepared to combine the major characteristics. The principal variables used for the overlays were length of the humid period, amount of excess water drainage density, lithology and morphology. In two of the largest agro-ecological units, the Mankran and Jolo-Kwaha watersheds were, respectively, selected for the semi-deciduous Equatorial Forest and Guinea Savana zones (Fig. 1) for semi-detailed characterization. They were designated as key areas for the study.

At this level (semi-detailed), data were collected in the selected key areas through field surveys using transects and observations on the physical environment and land cover/use of inland valley systems. This level of activity started with interpreting aerial photographs (scale 1:25,000-1:50,000) of the key areas, emphasising the distribution of inland valleys and their shape, the extent of the watersheds, land cover and infrastructure. Nine transects were cut for the site representing the Guinea Savanna zone, and 30 transects for the semi-deciduous Equatorial Forest zone. These transects cut across different segments of the valleys, from one top of the crest to the other. Several physical characteristics were described or measured along each transect. These were mainly related to gradient, soils and hydrology. Special attention was given to the hydromorphic fringes and the valley bottoms.

Soils were sampled for physical and chemical analyses in the laboratory according to land sub-elements (crests, slopes and valley bottoms) using standard methods. Soil samples were collected for the respective areas along the toposequence. They were dried and sieved through a 2-mm screen before analysis. For organic C, total P and total N analyses, the soil samples were ground to pass a 0.25-mm screen. For the analysis reported in Table 1, a glass electrode using a soil to water ratio of 1:1 measured soil *p*H. The pipette method was used for particle size distribution (Gee & Bauder, 1986). Organic C was determined using Wakley-Black method (Nelson & Sommers, 1982). Bray I extractable P (Bray I) was determined colorimetrically using the phosphomolybdate blue colour method (Bray & Kurtz , 1945). Total N was determined as described by Bremner (1996). Exchangeable potassium (K), calcium (Ca) and magnesium (Mg) (Jackson, 1967) and cation exchange capacity (CEC) (Chapman, 1965) were also determined.

Land cover and use were described for a strip of 200 to 400 m width along the transect line. Actual strip width depended on the density of the natural vegetation. The minimum size of individual land cover/use units to be described was set at 250 m². Crops, fallow and annual vegetation were described for type, species, land and crop management. Land use sub-units were distinguished as land with annual crops (cassava, rice, cowpeas), land with perennial crops (cocoa, citrus, oil palm), prepared land, young fallow (<10 years old), old fallow (10-30 years old), grazing land (managed or unmanaged), grassland, forbland savanna and shrubland, woodland and forests, infrastructure or wasteland.

Farmers were interviewed for additional information on flooding features of the valley bottoms, crops and crop rotations, production levels, land tenure, inputs (labour, fertilizers), and constraints. The results recorded per transect were processed into an agro-ecological diagram showing the physical parameters in a cross section, in combination with a map showing the land use pattern. Selected land use parameters such as valley bottom ratio (VBR), land use ratio (LUR), fallow index (FI), and soil preparation index (SPI) (Table 2) were quantified to facilitate the

TABLE 1

*Major Components of the Characterization Levels of Inland Valley Systems (IVS): Their Scales, Objectives and Time They Were Executed in Ghana**

Level of characterization	*Scale*	*Unit of analysis*	*Data collected*	*Source of information*	*Time frame*
Macro	1:500,000 to 1:1,000,000	Agro-ecological zone	Characterization of agro-ecological zones subdivided into agro-ecological units (physical and socio-economic); e.g. landform and major lithology	Literature	1994
Reconnaissance	1:250,000 to 1:100,000	Ghana (country)	Characterization of agro-ecological sub-units on the basis of rainfall, length of the humid period, landform, lithology, drainage density, major upland soils, major land use, population density. Selection of key areas	Secondary information rapid inventories (soils and land use)	1995
Semi-detailed	1:25,000 to 1:50,000	Mankran or Jolo-Kwaha (key area)	Characterization of valley systems based on soils and valley morphology, periods of flooding and groundwater depth, size of watersheds, land use ratios (per land sub-element and at valley level), crop rotations, socio-economics (e.g. market, land tenure and infrastructure). Selection of inland valleys	Satellite imagery, aerial photographs, transect surveys, farmer interviews	1996 to 1997
Detailed	1:10,000 to 1:50,000	Apotosu valley	Characterization of inland valleys on the basis of variations of soils and valley morphology , soil fertility and toxicity, soil physics (e.g. infiltration and permeability), flooding and groundwater dynamics, farming systems and cropping intensities, inputs-output, crop varieties and cropping calendar. Quantification of constraints	Aerial photographs, detailed surveys, farmer interviews, monitoring, experiments and simulation modeling	1996 to 1999

* Adapted from Van Duivenbooden & Windmeijer (1995)

Fig. 1. Map of Ghana showing the proportion of the major agro-ecological units generated at the reconnaissance level of characterization and digitised maps of Mankran (a) and Jolo-Kwaha (b) key sites.

comparison of different valleys or different land sub-elements within and between valleys.

Detailed characterization was based on a dynamic integrated transect method. The method allowed for information to be collected on the physical and biotic characteristics of inland valley systems. Eight transects were laid (across the inland/upland continuum) within the study area along the different valleys: 'Gold valley', 'Rice valley', and the 'Dwinan valley' (1996-1999). Soils were identified by mini-pits (dug to 60 cm) and supplemented by augering to 100 cm (where possible). Each soil layer was sampled and analysed for selected physico-chemical properties using soil-testing methods as described above. Perforated polyvinyl chloride (PVC) pipes were installed along the eight transects to monitor the groundwater and water dynamics for the 3-year period (1996-1999). Changes in groundwater depth, land use over time, and mean monthly rainfall were recorded. Flooding behaviour in the valley bottoms and the period of stream flow were measured.

Results

Ghana is on West Africa's Gulf of Guinea and lies between 4^0 3' -11^0 N latitude and $1^0$10' E - 3^0 15'W. Its land boundaries measure a total of 2,093 km. The total area is 239,340 km^2, with the solid land area measuring 230,020 km^2. The two major agro-ecological zones selected for Ghana were the Equatorial Forest and the Guinea Savanna zones. The geology and lithology showed that the land areas were derived from upper and terminal pre-Cambian rock. In the Guinea Savanna zone granites, migmatites and tertiary sedimentary deposits were recorded, while Paleozoic upward sandstones were observed for the Equatorial

TABLE 2

Definitions of Selected Valley Parameters Evaluated at the Semi-detailed Level of Characterization in the Mankran and Jolo-Kwaha Inland Valley Systems of Ghana

Parameter	*Definition*
Valley bottom ratio (VBR %)	The ratio occupied by the higher parts of the valley (crests, slopes and fringes) over the area of the valley bottom
Land use ratio (LUR %)	The area under agricultural use (annual crops, perennial crops, prepared land and young fallow over a total area (transect)
Young fallow ratio (YFR %)	The ratio of the area under fallow (=10 years) over the total area (transect)
Old fallow ratio (OFR %)	The ratio of the area under fallow (=30 years) over the total area
Actual production ratio (APR %)	The area under agricultural use (excluding grazing and young fallow) over the total area (transect)
Fallow index (FI)	The quotient of the area under young and old fallow over the total area (transect)
Actual cropping ratio (ACR %)	The ratio of the area of cropped land (annual + perennial + prepared land) over the total area (transect)
Annual cropping ratio (ACR2 %)	The ratio of the area under annual crops over the total area (transect)
Perennial crop ratio (PCR %)	The ratio of the area under perennial crops over the total area (transect)
Soil preparation index (SPI %)	The ratio between the area that has been tilled (ploughed or the construction of beds, bunds) over the total of cropped land (annual and perennial crops) and prepared land

Forest zone. The Equatorial Forest occupies most of southern Ghana with a growing period of over 270 days. The annual rainfall is bimodal, with an annual precipitation between 1200 and 2000 mm. Drought stress and the annual diurnal temperature fluctuations are low. In the Guinea Savanna zone, rainfall distribution is unimodal and the mean annual rainfall is 900-1400 mm. The growing period is between 165 and 270 days.

Excess of precipitation, length of the humid period, lithology, morphology, and drainage density were the five main characteristics used to determine the agro-ecological units at the reconnaissance level of characterization. Using graphical and statistical methods (cluster analysis), 10 main agro-ecological units were defined.

Two key areas, Mankran and Jolo-Kwaha, were chosen as two of the most extensive agro-ecological units (Table 3). The Mankran key area is in the semi-deciduous Equatorial Forest zone. The ecological system is in the Ahafo-Ano South District of the Ashanti Region along the main Kumasi-Sunyani road. The coordinates of the site are 1^o 40′ W and 2^o 00' W and 6^o 45′ N and 7^o 00′ N. The Mankran valley system has a catchment area of 250 km^2. It lies between the 30-km point and 35-km point on the Kumasi-Sunyani road, North-West of Kumasi. The Jolo-Kwaha system represents a main agro-ecological unit in the Guinea Savanna. The valley drains the western fringes of Tamale (the administrative capital of the Northern Region of Ghana) with catchment of about 898 km^2. The coordinates are 1^o 05′ W and 1^o 10′ W longitude and 10^o 18' and 10^o 25' N latitude.

TABLE 3

Area and Proportion of Major Agro-ecological Units in Ghana Generated with Five Major Variables for Ghana at the Reconnaissance Level of Characterization

Classified identification	*Area (km^{-2})*	*Percent of area*
8	4840.6	2.0
10	6106.4	2.6
6	10093.2	4.2
4	10769.3	4.5
5	11857.6	5.0
7	19116.7	8.0
1	21403.8	8.9
3	29183.6	12.2 Mankran's location
2	29583.3	12.4
9	96363.0	40.3 Jolo-Kwaha's location
Total	239,340.6	100

Table 4a shows the contrasting characteristics of the agro-ecological units, represented by the two key areas. Contrasting differences in the rainfall pattern, length of the humid period, and annual precipitation are observed between the two key agro-ecological units (Table 4b). Mean monthly temperature (26 °C) is, however, the same for the two units. Drainage density is higher (1.2-2.4 km^{-2}) for the semi-deciduous area compared with 0.6 km^{-2} for the Guinea Savanna area. Major cash crops for the semi-deciduous zone are cocoa, cola, citrus, plantains and oil palm (perennials). Rice, groundnuts, cotton and tobacco (annuals) cultivation prevail in the Guinea Savanna zone. Population density in the Equatorial Forest zone (104 persons km^{-2}) was higher than that in the Guinea Savanna zone (25-45 persons km^{-2}), suggesting that southern Ghana is more populated than the northern parts where the predominant vegetation is Guinea Savanna. Land tenure systems are the same for the two systems because a clan, chiefs, individuals, or families own them; otherwise, individuals own land. Road network is moderately good for the two systems, and the number of market centres for the two agro-ecological zones is comparable.

Semi-detailed characterization

The Mankran valley system is drained by the Mankran river. The area as a whole has a rolling topography (10-30%). Altitudes range between 210 and 290 m above sea level. Along the catena, local height difference from the crests to the valley bottoms is in the range of 10 to 25 m. Jolo-Kwaha watershed falls within the White Volta Basin with a flat to gentle undulating topography. The uplands have a slope of 0.5 per cent, and altitudes range between 5 and 15 cm above sea level.

For the Mankran valley system, the first order valley (Fig. 2a) was as wide as 800 m compared to the second order valley which was 1000 m wide (Fig. 3a). The third order valley was as wide as 1200 m (Fig. 4a). Valley bottom width was widest in the third order valley (300 m), whereas it was 150 m in the second order and nearly 100 m in the first order. Slope was 30 per cent in the first order valley in the Mankran system, but was only 5 per cent in the second order and ranged between 4 and 5% in the third order valley. Most fringes and slopes (land sub-elements) of the first order were not cultivated, and it was mainly covered by shrubs and designated as forbland. In the second order valley in this system, more crops were cultivated compared with the first order. Crops such as cocoa, oil palm, cassava and beans were cultivated, although the valley bottom lands were not cropped but had grasses and forbland. In the third order valley, settlements were found on either side of the transect; vegetables, cassava, cocoa and oil palm were commonly cultivated.

Valleys in the Jolo-Kwaha system contrast sharply with those of the Mankran system. The first order valley (Fig. 2b) was as wide as 1300 m compared with the second order valley (Fig. 3b) which had a width of 1500 m, and the third order valley being less as wide (1100 m) (Fig. 4b). The slopes in this system were much gentler, varying between 2 and 3 per cent in the first and second order valleys. As in the third order valley, the

TABLE 4a

Selected Valleys' Features and Soil Fertility Characteristics Calculated at the Semi-detailed Level of the Mankran and Jolo-Kwaha Key Areas in Ghana

Parameter	*Mankran*	*Jolo-Kwaha*	
Total area (ha)	97.5	26	
Crests	17	6.8	
Slopes	46.3	16.1	
Fringes	17.6	2.7	
Valley bottom	16.6	1.3	
Average width (m)			
Total valley	1000	1267	
Crests & slopes	786	1070	
Fringes	57	67	
Valley bottom	157	130	
Slope gradient (%)	2-5	Flat-0.05	
Slope form	Rectilinear/concave	Rectilinear/concave/convex	
Ferric Luvisol			
Soil *p*H (1:1 H_2O)	5.0	*p*H for crests	5.7
Base saturation (%)	97	*p*H for fringes	5.0
Clay (%)	3.8	*p*H for valley	4.3
Carbon (%)	2.6		
N (%)	0.3		
($Al + H^+$)	0.5		
CEC (cmol kg^{-1})	14.5	Carbon (%)	
		Crests	0.9
		Fringes	0.9
		Valley	0.9
Ferric Acrisol			
Soil *p*H (1:1 H_2O)	7.2		
Base saturation (%)	99		
Clay (%)	12.8		
Carbon (%)	2.0		
N (%)	0.4		
($Al + H^+$)	0.75		
CEC (cmol kg^{-1})	55.5	Available P (mg kg^{-1})	
		Crests	5.5
		Fringes	2.5
		Valley	2.5
Dystric Gleysol			
Soil *p*H (1:1 H_2O)	4.7		
Base saturation (%)	95		
Clay (%)	24.2		
Carbon (%)	2.9		
N (%)	0.2		
($Al + H^+$)	0.85		
CEC (cmol kg^{-1})	17.4		

TABLE 4b

Differences in Rainfall Pattern, Length of the Humid Period and Annual Precipitation Recorded for the Two Key Sites

Parameter	*Mankran watershed*	*Jolo-Kwaha watershed*
Rainfall pattern	Bimodal	Unimodal
Annual precipitation (mm/year)	1410 (medium)	1120 (medium)
Annual PET* (mm/year)	1670 (high)	2420 (very high)
Length of the humid period (days)	153 (medium)	61 (very short)
Surplus of precipitation in humid period (mm)	150 (very low)	60 (very low)

* PET= Potential evapo-transpiration

slope was as low as 0.3-0.5 per cent. Valley bottomlands were much narrow (150 m wide) compared with those of the Mankran system in the first order. In the second order valley, two distinct valley bottoms were identified; one about 100 m and the other about 60 m wide. In the third order valley, the valley bottom was only as wide as 80 m. Crops grown in the Jolo-Kwaha system were largely annual crops, notably hydromorphic and upland rice, maize, millet, yam, sorghum, cassava, ground-nut and vegetables. Small patches were left out as fallow lands.

Sedimentary rocks of Upper Voltaic Formation underlie the Jolo-Kwaha key area. Rocks of this unit consist predominantly of shales with sandstone, arkoses and layers of conglomerates and mudstones. Shale and mudstone are frequently micaceous. Soils of the Mankran watershed are developed on Birrimian rocks. These rocks consist of phyllites, greywacke, schists and gneiss. Veins and stringers of quartz injected into the phyllite break up during weathering to give stones and gravel, which are locally abundant. Valley fringes and bottoms are, respectively, developed from colluvium or colluvial-alluvial materials derived from these formations.

The major soils found were Ferric Luvisols, Ferric Acrisols and Dystric Gleysols (Table 4). The *p*H of the Ferric Luvisols was 5.0, 7.2 on the Ferric Acrisols, and 4.7 in the valley bottoms

5 - 15% gravel

15 - 40% gravel

oil palm

Fig. 2. Cross-sectional features of a first order valley generated from transect studies of Mankran (a) and Jolo-Kwaha (b) key sites at the semi-detailed level of characterization.

(a)

(b)

Relative elevation (m)

Horizontal distance (m)

Fig. 3. Cross-sectional features of a second order valley generated from transect studies of Mankran (a) and Jolo-Kwaha (b) key sites at the semi-detailed level of characterization.

(a)

(b)

Relative elevation (m)

Horizontal distance (m)

Fig. 4. Cross-sectional features of a third order valley generated from transect studies of Mankran (a) and Jolo-Kwaha (b) key sites at the semi-detailed level of characterization.

(a)

(b)

Relative elevation (m)

Horizontal distance (m)

Fig. 5. Unified legend for the cross-sectional features of the valleys for the key sites and of which valley characteristics were evaluated at the semi-detailed level of characterization.

(Dystric Gleysols). The soil reaction for the crests of the Jolo-Kwaha was 5.7; but 5.0 and 4.3, respectively, for the fringes and valley bottoms. Carbon content generally varied, irrespective of whether it was in the upland or in the lowland, for land sub-units of the Mankran watershed. For Jolo-Kwaha, it was 0.9 irrespective of the position of the toposequence (Table 4). Data for the detailed characterization of the valleys are not presented here, but generally, the topsoil showed low to moderate levels of phosphorus. Topsoil values were much higher than the subsoil values. This, it was thought, could be due to the effect of mineral cycling in the citrus and cocoa plantations. Soils of the valley bottoms were slightly acidic in the topsoil (*p*H 5.2-5.9), but highly acidic in the subsoils (*p*H 4.2-4.5). The valley bottomlands are better supplied than the upland with exchangeable cations, especially more mobile cations Ca^{2+} and Mg^{2+}. Nitrogen levels in the lowland soils, however, showed a trend similar to that of the upland soils. Although the topsoils were relatively rich in nitrogen, the subsoils were extremely poor in total N and organic C.

The driest year of the study period was in 1997. The topsoil saturation was nearly equal to zero, and the saturation started only in June to July, except for Gold Valleys. However, in the other two years, topsoil started to saturate in May, about 1-month delay from the peak of rainfall. The months of the lowest groundwater levels were February and March. The fluctuations in water table almost corresponded to the flow of seasonal streams. The streams dry up in the dry season until the groundwater table rises to the surface in the riverbed in late May or early June in the selected valleys, depending on the intensity of the year's rainfall. The flow of water stops as soon as the rain stops in Gold Valleys, because vegetation in their catchment areas has been considerably removed. The stream in the first order valley flowed for about 4 months during June to October, whereas the stream in the second order valley flowed for 6 to 7 months during May to December.

The major differences in the two key sites are further shown by the data in the selected valley characteristics (Table 5). The valley bottom ratio (VBR) was 95 per cent for Mankran and 92 per cent for Jolo-Kwaha, and shows that the areas to be classified as 'valley bottom' were about the same size in the two valleys. However, differences were recorded for the land use ratio (LUR), actual production ratio (APR), and the actual cropping ratio (ACR). The fallow index (FI) for the valley bottom at Mankran was 1, and an indicator that the land in this key site was mostly fallow, but contrasts that of Jolo-Kwaha (0.12). Perennial crop ratio (PCR), young fallow ratio (YFR), and old fallow ratio (OFR) all indicate the different land use systems prevailing in the two key sites. The soil preparation index (SPI) of 100 per cent recorded for Jolo-Kwaha key site contrasted the zero (0) recorded for the Mankran site, and shows the extent to which soil tillage equipment has been used at the Jolo-Kwaha site compared with the Makran key site (Table 5).

Hydrological information from the detailed characterization show that it should be possible for appropriate water-harvesting techniques and devices to be put in place at the valleys studied. Nutrient retention, weed control through water management under improved paddies may be useful options.

Discussion

Inland valleys have become very important in the general agricultural output of West African countries. Therefore, it is important to understand the constraints that will lead to the proper development of these sometimes hardly unused land resources. Research on inland valley characterization has erroneously tended to link it with rice cultivation (Carsky, 1991). Earlier reports on inland valley usage have not clearly defined the land sub-units for consideration, especially the scales and exact measurements that may need to be used to handle these sub-units. Reports by Andriesse & Fresco (1991) and Windmeijer & Andriesse (1993) suggested some concepts,

TABLE 5

Weighted Averages of Selected Valley Characteristics for the Land Sub-elements of Valley Systems at the Semi-detailed Characterization Level of Mankran and Jolo-Kwaha Valley Systems in Ghana

Calculated property	*Mankran*	*Jolo-Kwaha*
Valley bottom ratio (VBR)	95	92
Land use ratio (LUR %)		
Total	27	88.7
Crests	10	77.2
Slopes	34.5	89.8
Fringes	6.0	100
Valley bottom	23.3	100
Actual production ratio(APR %)		
Total	12	66.2
Crests	8.0	60.3
Slopes	32.0	68.3
Fringes	7.0	78.3
Valley bottom	0.0	87.9
Actual cropping ratio (ACR %)		
Total	4.8	65.8
Crests	5.4	60.3
Slopes	6.3	68.3
Fringes	7.5	78.3
Valley bottom	0.0	87.9
Fallow index (FI)		
Total	0.5	0.28
Crests	0.2	0.25
Slopes	0.2	0.13
Fringes	0.6	0.22
Valley bottom	1	0.12
Perennial crop rotation (PCR %)		
Total	10	0
Crests	19.5	0
Slopes	20.0	0
Fringes	0	0
Valley bottom	0	0
Young fallow ratio (YFR %)		
Total	9	22.9
Crests	2.0	17.0
Slopes	2.5	22.0
Fringes	9.2	22.0
Valley bottom	23.3	12.0
Old fallow ratio (OFR %)		
Total	1	1.9
Crests	0	2.1
Slopes	4.5	1.5
Fringes	0	0
Valley bottom	0	0
Soil preparation index (SPI)		
Total	0.03	100
Crests	0.1	100
Slopes	0	100
Fringes	0	100
Valley bottom	0	100

definitions and approaches related to agro-ecological characterization of inland valley agro-ecosystems in West Africa and advanced some methodological proposals. Those reports attempted to provide elements for a methodological framework for inland valley research. In an attempt to test the methodology, this paper focussed on the morphology and hydrological characteristics and characterization of typical inland valley agro-ecosystems at different levels of detail. For example, definitions of inland valley systems are now appreciably clear, and description of the main landscape elements (uplands, slopes, hydromorphic fringes, and valley bottoms which constitute an inland valley) can be easily understood. These landscape elements can be related to different hydrological regimes occurring along the toposequence (i.e. the pluvial, phreatic and fluxial zones). It also negates the idea that inland valleys are exclusively for rice cultivation. Fig. 2-4 show that longitudinal differentiation of inland valleys is important, as are the different flooding regimes in them.

Overall, this study used a stepwise approach to characterize inland valley agro-ecosystems, as proposed by Andriesse & Fresco (1991). The report is an example of a sequential characterization at the macro and semi-detailed levels of detail. Thus, the study attempted to (i) use the stepwise method, which includes an extra characterization step, at the reconnaissance level (i.e. map scales between 1:100,000 and 1:250,000) so that the gap between macro-level and semi-detailed characterization could be better bridged; and to (ii) test the use of a minimum dataset for each of the characterization levels needed to be defined, considering the need for aggregation of characterization parameters when going up on the scale ladder and, conversely, dis-aggregation of parameters when going down the various characterization steps as proposed by earlier studies.

The study also brought to the fore the essential differences between the two key sites and the nature of the land use intensities and systems for the areas in the semi-deciduous and savanna areas of Ghana. Using land use evaluation methods of APR and ACR and others, and also the SPI can show how the land use systems in the two valleys vary. It helps one's understanding on how the use of different scales allows for different details to be observed and, therefore, the need to carefully identify the methods for intervention. Use of secondary data and statistics will allow for overlays to be produced and major statistical characteristics to be identified. However, at the level of semi-detailed characterization, exact indicators and land use properties are identifiable at precise scales. For example, measuring soil physical and chemical characteristics is more exact with less margins of errors compared to using secondary data at the reconnaissance level of characterization.

If inland valleys must be used solely for rice cultivation, it should be recognized that their suitability will largely depend on characteristics that are valley related and non-valley related. The static variables like climatic conditions, socio-economic factors and economic practices are important, although they cannot be changed by research. Some of these practices cannot be improved, but change only when supported by government policy. Because of the wide variability among inland valley systems, Otoo & Asubonteng (1995) pointed out that the great heterogeneity of areas makes the application of inland valley rice development more difficult, particularly concerning engineering and agronomy. The results of the semi-detailed characterization showed that soil-related problems might be common in the selected valleys and for which research and agronomic interventions may be needed. The risk of erosion was observed on valley slopes, but not in valley bottoms. Therefore, a different strategy may be needed to develop these different portions of the valley.

Developing bunds for water control may

dictate the regularity with which farmers will use and stay on the land for rice cultivation. However, working in inland valley swamps means drudgery for farmers who have to work in the paddies. Introducing small tractors and other equipment may change the situation in the Jolo-Kwaha area. The SPI of 100 per cent suggests that equipment use is high and may be readily adapted by the farming communities.

Conclusion

Multi-scale characterization, though needs a multi-disciplinary approach and may be time-consuming, is a necessary activity for the optimum and sustainable use of the many inland valleys scattered over Ghana. Whereas the results show that choice of scales and interpretation may depend on the accuracy desired, this study records the extent to which inland valleys differ in the country, and the application of a multi-scale characterization approach has been exemplified.

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