Technology Generation and Dissemination: The Role of Agro-ecological Characterization

'AGRO-ECOLOGICAL CHARACTERIZATION' and 'characterization' are terms banded about by agricultural researchers, but what do they really mean, and why is it so important to allocate enough resources to characterization as part of the overall agricultural research program? The Inland Valley Consortium (IVC) is coming to the end of its First Phase and characterization has been a major component of the research program. So the IVC presents the perfect case study.

WARDA has the Consultative Group on International Agricultural Research (CGIAR) ecoregional mandate for inland valley development in Sub-Saharan Africa. The Inland Valley Consortium (IVC) for the sustainable development of inland valley ecosystems is a CGIAR-supported System-wide ecoregional activity convened by WARDA in collaboration with national and international institutions working to improve the productivity and sustainability of inland valley land use systems.

Why characterize?

Farmers' fields are diverse in their characteristics. Compare one field with another and you may well find differences in soil structure, soil nutrient distribution and water dynamics, among other factors. Go to a different scale, and you will find that one farming region differs from another in the same respects, but also in population density, climate, geology, market accessibility and others. Modern agricultural research and development emphasizes the need for technologies (such as crop varieties, farming practices, appropriate machinery) to be specifically adapted to the biophysical environment and to the farmer's needs and resources. How then do we decide what are the most relevant sites for working with farmers to generate technologies and evaluate them, and whether a technology developed for one farm or farming region is suitable for a farmer or farming region elsewhere in the country or even in another country altogether? Trial and error is simply too expensive, time-consuming and wasteful of resources. The answer for saving resources is to work in suitable test sites, which can be identified through characterization—cataloging the characteristics of farm communities and farming regions to determine broad and specific similarities and differences.

The general term characterization is often used for specific descriptions. Agro-ecological characterization is a much broader approach and means a holistic description of agro-ecosystems, including the biophysical and socioeconomic characteristics. The IVC developed a multi-level agro-ecological characterization approach. This approach allows the selection of important and representative sites for technology generation and evaluation, and the quantification of the main constraints to agricultural intensification and diversification. Moreover, the results of the agro-ecological characterization will be the basis for technology transfer. Another application for agro-ecological characterization is as an aid for setting research priorities. As we determine the characteristics of inland valleys and the farming communities within them, we will find some for which there are no technologies currently available. This information feeds back into the research-prioritization process to enable technology-development research to be targeted at the most needy farming systems.

Great potential for food security

The inland valleys are defined as the upper reaches of the drainage systems. Here, the dynamics of the water flowing through the system are quite low, and may be controlled by relatively simple water management systems. Larger floodplains are excluded from the definition. Inland valleys can be divided along the toposequence (cross-section) into three different land units (see Figure 4). The uplands (crests and slopes) are the well-drained higher parts of the system. The valley bottoms are the lower parts, subject to flooding during the rainy season. The hydromorphic fringes are the adjacent strips of land that have a groundwater table near the surface during the rainy season, which is an extra source of water for the crops grown in this zone. Inland valleys present great potential for agricultural expansion and intensification in West Africa, to help feed the fast-growing populations.

The IVC was created in 1993 to explore the potential for intensification and diversification of the valley bottoms and their hydromorphic fringes. It is estimated that there are between 20 million and 50 million hectares of this habitat throughout West Africa (the wide range is explained by the use of different definitions by various institutions and individuals, and the incomplete knowledge of the whole landmass of the region). Of this area, it is again estimated that only 10–25% is under cultivation—hence the scope for expansion. If an extra 2 million hectares of this land were used to cultivate rice alone, at an average yield of 3 tonnes per hectare, the West Africa region could halt the expensive importation of rice from elsewhere! And, this is only looking at the rice crop. Inland valleys present equally great potential for crop diversification, such as vegetables, banana and cassava.

But...

However, just like any other farming ecology, or potential farming ecology, inland valleys are diverse, especially taking into account the hydrology of (that is, water movements within) inland valleys. It is generally understood that the basis for cropping intensification anddiversification of the inland valley lowlands starts with improving the water management there. A certain level of water control will allow the introduction of more productive, improved rice cultivation practices. Full water control is not a good option for the inland valleys—because the lowlands cover a limited area, the cost of full water control will never be covered by the increased rice production. A much better option is to go for relatively simple, low-cost water management systems. But, enough information needs to be available to select a good system. Hydrological characteristics depend on more than just rainfall. Other parameters such as lithology (base rock), land use intensity on the adjacent uplands, and morphology play a major role in determining the overall hydrological dynamics of the lowlands. Characterization is the key to understanding the dynamics of the system and identifying technologies developed elsewhere which are, or could be, adopted at or adapted for a particular target site. The more similar the target site to another site where technologies have already been successful, the more likely those technologies will be able to improve farming in the target area. Where appropriate technologies are lacking, the characterization generates all the information required to develop technologies to overcome the prevailing constraints. However, when we decide to characterize even a field there are numerous measurements we could make, both physical—for example, daily temperature regime, water and nutrient flows—and socioeconomic—for example, availability of fertilizers and pesticides, farm income, proximity to market or trade routes. Clearly, to collect all such information would take a very long time, and is totally impractical. From experience, the Consortium identified ‘minimum data sets’—see box (page 26)—which should allow sufficient characterization for the purposes of technology generation, evaluation and transfer. But even these are too much for one institution to collect and collate.

The approach for agro-ecological characterization

This is where the Consortium concept comes into its own. The Consortium brings together national and international organizations in a research and development partnership that capitalizes on the strengths of each partner and makes the work more efficient (see box, page 28). Even within a partnership, there is still a danger that information collected by the various partners may be incompatible or not comparable. Thus, one of the first tasks of the IVC was to determine standardized methods of data collection to be used by all the partners. In this way, a valley in, say, Nigeria can be directly compared with one in, say, Mali.

“But,” you may well ask, “we are talking about at least 20 million hectares. How are we to compare farming communities and valleys over such a wide area?” Of course, we cannot possibly characterize each farming community in every inland valley in West Africa; so, the IVC developed a four-tier system of characterization. **Broad**, or ‘**macro**,’ characterization is done across the whole region; then, ‘**reconnaissance**’ characterization is done at the national level; thirdly, ‘**semi-detailed**’ characterization is conducted for a small region; and, finally, ‘**detailed**’ characterization is done for single inland valley system (see Figure 5, page 27). The medium-term plan is to relate the detailed characterization to the other levels and determine which biological, physical or climatic characteristics at the more general levels have the greatest influence on the characteristics of the valleys at detailed level. Once this is done, preliminary targeting of technologies may be done from reconnaissance or semi-detailed characterizations.

'Minimum data sets' for three levels of agro-ecological characterization as used in Phase I of the IVC

Discipline	Level		
	Reconnaissance	Semi-detailed	Detailed
Agronomy	Main crops; lowland area cropped (%)	Land use; crop types, associations, rotations; fertilization; crop protection; water management; potential constraints; mechanization; animal husbandry	*Crops:* variety; cycle; density; planting method; management sequence; associations and rotations; agroforestry; organization and length of fallow; production; yield-limiting factors; inputs; land and water management *Livestock:* description, watering points
Socioeconomics	Administrative units; ethnic groups; population density and distribution; main activities; infrastructure and markets	Population (demography, gender and ethnic group related activities, migration); infrastructure (markets, roads, schools, health); land and water tenure (access to lowlands, gender, ethnic groups, traditional beliefs); production aims; extension service activities	*Farms:* family size, composition and ethnic group; labor availability; gender and land tenure; distance to fields *Economy:* prices of inputs and outputs; incomes; markets, distance, supplies, input purchase, credit Farmers' organization; land tenure and water management; subsidies; development agencies; health; education; farmer perception of technologies
Climatology	Rainfall regime; potential evapotranspiration; length of humid period and surplus of water; temporal variability	As Reconnaissance	Daily precipitation data; minimum and maximum temperature; radiation; average wind speed; atmospheric pressure; relative humidity; evapotranspiration; pan evaporation
Geology	Morpho-structural unit (sedimentary basin, basement complex); lithology	Lithology	Lithology
Geomorphology	Land form, slope classes, relief	Description of land sub-elements (slopes, length, width, surface); area of watershed	Land sub-elements and their erosion risks; erosion features and indication of severity; analysis of major erosion-controlling factors
Soils	Major soil units (from national and FAO systems)	Characteristics along toposequence; chemical and physical analysis; degradation; classification (national and FAO)	Standard description to 1.2 m; depth of impermeable layer; general biological activity, condition and degradation risk to top-soil; detailed chemical and physical analysis
Hydrology	Drainage density	Flooding characteristics (frequency, depth, period); stream discharges (if data available); groundwater table fluctuation; water quality; drainage density	*Surface water:* total discharge; base flow; discharge regime; water quality; model rainfall– discharge *Sub-surface water:* fluctuations in groundwater table; sub-surface flow; water quality
Flora	Type of general vegetation; classification	Type of vegetation characterizing different land sub-elements; classification	Vegetation structure, composition, cover (by land sub-element)

Partners in the Inland Valley Consortium

Countries (partners include NARS, extension services, NGOs and universities)

- Benin
- Burkina Faso
- Cameroon
- Côte d'Ivoire
- Ghana
- Guinea
- Mali
- Nigeria
- Sierra Leone
- Togo

International Institutions

- West Africa Rice Development Association (WARDA/ADRAO)
- Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)

- Food and Agriculture Organization of the United Nations (FAO)
- International Institute of Tropical Agriculture (IITA)
- International Livestock Research Institute (ILRI)
- Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO)
- Wageningen Agricultural University (WAU)

Collaborators
- Institut de recherche pour le développement (IRD, formerly ORSTOM)
- Conférence des responsables de la recherche agricole en Afrique de l'Ouest et du Centre (CORAF) networks
- International Water Management Institute (IWMI)
- International Program for Technology Research in Irrigation and Drainage (IPTRID)

Donors
- The Netherlands (DGIS)
- France

The actual approach for agro-ecological characterization is not a final output by itself. After the characterization of 15 key areas in 10 West African countries, we will have a much better understanding of the inland valley systems and the parameters at the differentlevels which are the main driving characteristics for inland valley properties. The final output of the characterization exercise will be decision tools for technology selection and transfer, with methods for the most efficient collection of the required data. This should represent a major saving in research investment.

The data collected at each level of detail are different, both qualitatively and quantitatively, and so are the tools used to collect them. For **macro characterization**, the major agro-ecological zones of the region are identified on the basis of the length of the crop-growing season. This is combined with other data, such as lithology and morphology, taken from other national and regional studies to define ‘agro-ecological units.’

Reconnaissance characterization also depends heavily on information from other sources (for example, maps and reports), but may also involve discussion with extension services on broad agricultural characteristics, and quick field inventories of land use and farming systems. The idea of the reconnaissance characterization is to divide the macro agro-ecological units into agro-ecological sub-units, using parameters which will not change at more detailed levels, such as lithology, rainfall, major cropping system, population density and drainage density.

Semi-detailed characterization is carried out on a ‘key area’ of 50 × 50 km (2500 km^2) representative of a reconnaissance-level agro-ecological sub-unit. Satellite images and aerial photographs are used to identify four watersheds (each comprising at least so-called first-, second- and third-order valleys). Interviews are conducted at each village using the watershed to generate village-level (rather than farm-level) data, and transect (cross-section) studies are made at 8–10 places in the watershed for morphology, soils and land cover. After all these data are processed, one valley system which is most typical for the agro-ecological sub-unit is selected for detailed characterization.

The main objectives of the **detailed characterization** are to understand the functioning of the inland valley agro-ecosystem, to quantify the constraints andproduction potential, and to assess the variability of characteristics within the inland valley.

In particular, the variability of water availability along the valley affects technology development and evaluation. Detailed characterization involves socioeconomic and agronomic interviews at household and individual level; observations of farming practices; detailed measurement of biological and physical aspects of the farming ecology; detailed measurements of rainfall and water movements; and surveys of soils and land use.

It is this detailed characterization that enables us to identify the farm-level problems in the farming systems, and it is mostly these problems that have to be addressed by the technologies developed by agricultural research. Thus, if we can find links between characteristics at the reconnaissance and semi-detailed levels of characterization which can be used to predict the characteristics at the detailed level, and therefore the problems facing farmers in a particular system, we should be able to identify technologies which have good potential for adaptation and adoption in the target watershed. Where these technologies do not exist, the same approach gives feedback to research on technologies to be developed.

The agro-ecological characterization approach has elements of known research procedures. Agro-ecological characterization through biological and physical measurements such as climate, soil, and seasonal changes in water availability is standard methodology. So too, are the socioeconomic studies used in this work, although these are much more difficult to quantify. What is novel about the IVC approach is the combination of biophysical and socioeconomic characterization at different levels of scale. A second novelty in our approach is that all the stakeholders (scientists, farmers, extension officers, etc.) are working together in the key sites on constraint analysis and selection of technologies to be evaluated or to be generated.

Although Phase I is almost complete and not all the characterization has been done, it cannot be assumed that implementation of the approach takes five years. Considerable time was allocated in the first two years to developing the common methodology, and bringing together and organizing the different stakeholders in the IVC member countries. In addition, the macro and reconnaissance characterization are only conducted once. In new key sites only the semi-detailed and detailed characterizations have to be implemented. The 'minimum data sets' collected in Phase I are now available for assessment. We will use this to identify the essential data sets for future characterization, which will consequently be smaller and therefore easier to collect. This will include identifying the most efficient ways of sampling the defined parameters; for example, it may be determined that a critically timed measurement of water flow once per year can be used instead of monitoring throughout the year—we aim to develop such rapid appraisals to replace detailed measurements. With the refined minimum data sets and the rapid appraisals, full characterization can be implemented in 1 to 2 years.

Outputs from the IVC Phase I

Basic outputs

Much progress was made in the characterization exercise during the First Phase of the IVC (see map opposite). In a few countries, the agro-ecological characterization is yet to be finalized. This is due in part to the time that some countries became members of the IVC—this is the case for Guinea (1996), and Cameroon and Togo (1998).

Strategic outputs

In addition to the standard agro-ecological characterization, several countries carried out supplementary activities.

- The role of women (farmers) in the inland valleys (Benin and Ghana).
- A methodology to use satellite images at the semi-detailed level was developed (IITA).
- The potential for using the natural vegetation to characterize the extent of the hydromorphic zones (WAU).
- A set of socioeconomic indicators was devised for semi-detailed characterization (WARDA).
- All of the characterization data from Benin was uploaded to a comprehensive database (Benin).
- Much of the characterization data collected by the IVC partners was consolidated into a geographical information system (GIS) (IVC Regional Coordination Unit).
- A rapid appraisal to characterize the inland valley hydrology and a decision support system for the selection of the most appropriate water management technology in that valley were developed (CIRAD, Mali and Ghana).

Applied/adaptive outputs

Member countries that completed the characterization exercise proceeded with a plan of inland valley lowland development with active farmer participation. Two examples are given here.

Benin

In the Gankpétin key site, simple contour bunds were constructed by the farmers to improve water distribution in the slightly concave valley bottom. This resulted in considerable pay-offs:

- the cultivation of maize as a pre-rice (pre-flooding) crop was improved (in cooperation with IITA);
- rice production in the main season, when flooding occurs, has been increased by the introduction of improved varieties, modified planting density to combat weeds, and better use of fertilizers;
- post-rice cultivation of vegetables profits from the increased availability of residual water, due to the increased storage of water by the introduced water management system.

The introduced technology packages are so successful that farmers are spontaneously developing inland valley lowlands downstream of the project site.

Ghana

In the Mankran key site, rice alone is cultivated in the narrow and flat valley bottom. The rice fields were bunded, and a central canal constructed (for irrigation and drainage).

- The improved water management allowed the introduction of improved varieties and cropping techniques, including transplanting in rows, and the use chemical and organic fertilizers.
- Because this site is situated near Kumasi, farmers are producing rice for market (rather than for home consumption), and are able to invest more in fertilizers and other inputs.

Phase II—1999 and beyond

In 1999, most of the countries will start developing the lowlands of their key sites and evaluating improved production technologies. Where the technologies are adopted and adapted by the farmers in the key sites, the national extension services will be able to transfer the technologies to other farmers in the different regions.

In the second phase of IVC, starting in 1999, more emphasis will be put on technology evaluation and transfer. Apart from finalizing on-going characterization activities, some new characterization activities will be initiated. These will focus on quantification of the dynamic processes in inland valleys, including hydrology and nutrient fluxes, and the impact of land use changes on these dynamic processes. The results of this characterization will be used to estimate the impact of improved technologies on the natural-resource base, in other words, the sustainability of the newly introduced technologies.

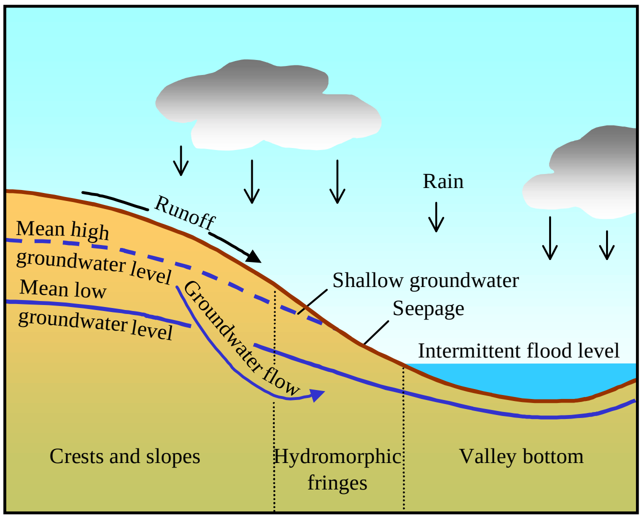

Figure 4. Simplified and stylized cross-section of an inland valley

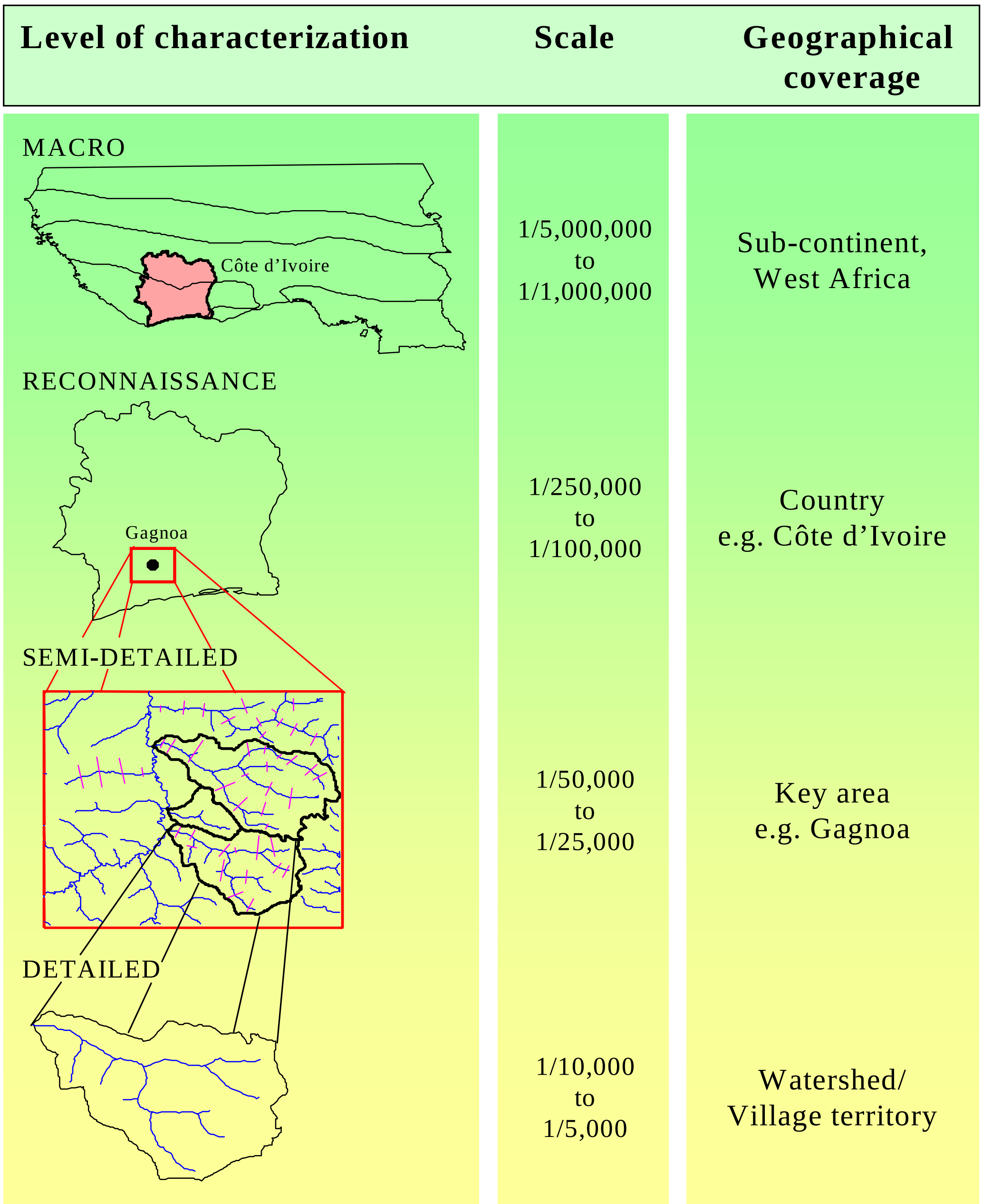

Figure 5. The four levels of agro-ecological characterization

Progress of agro-ecological characterization in IVC member countries