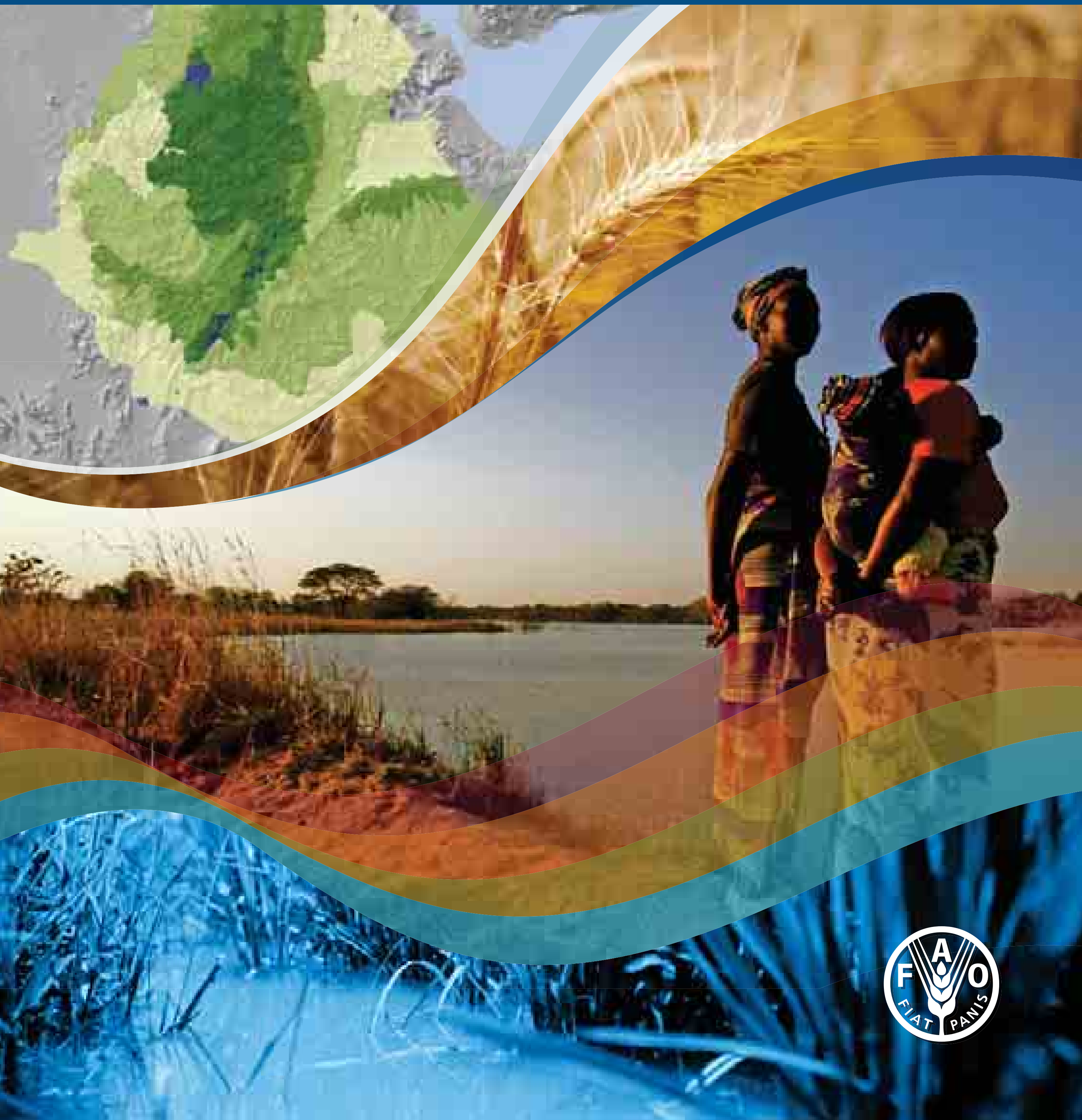
Assessing the potential for poverty reduction through investments in agricultural water management

A METHODOLOGY FOR COUNTRY LEVEL ANALYSIS



FAOWATER

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A METHODOLOGY FOR COUNTRY LEVEL ANALYSIS

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Abbreviations and acronyms

AEZ	Agro-ecological zone
AgWater	Agricultural Water
AWM	Agricultural water management
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
GMIA	Global Map of Irrigated Area
IDE	International Development Enterprise
IFPRI	International Food Policy Research Institute
IRWR	Internal renewable water resources
IWMI	International Water Management Institute
NRL	FAO, Land and Water Division
SEI	Stockholm Environmental Institute
SSA	sub-Saharan Africa
TLU	Tropical Livestock Unit

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which aimed to design agricultural water management (AWM) strategies for smallholder farmers in sub-Saharan Africa and India. The project was implemented by:

- International Water Management Institute (IWMI)
- Food and Agriculture Organization of the United Nations (FAO)
- International Development Enterprises
- International Food Policy Research Institute (IFPRI)
- Stockholm Environment Institute (SEI)

The Project was implemented in Burkina Faso, Ethiopia, Ghana, the United Republic of Tanzania, Zambia and in the States of Madhya Pradesh and West Bengal in India.

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Summary

Several studies have highlighted the potential of AWM for poverty alleviation. In practice, however, adoption rates of AWM solutions remain low and, where adoption has taken place locally, programmes to disseminate these solutions are often challenging. The overall goal of the project was to stimulate and support successful pro-poor; gender–equitable AWM investments, policies and implementation strategies based on concrete, evidence–based knowledge and decision–making tools.

The *AGwater* solutions project examined AWM interventions at the farm, community, watershed, and national levels. It has analysed the opportunities and constraints of a number of small–scale AWM interventions in several pilot research sites across the different project countries, and assessed their potential in different agro–climatic, socio–economic and political contexts.

Contrary to classical water investment planning processes, this approach focuses on addressing the needs of poor rural people, rather than focusing on the development of potentially suitable resources. In so doing, the demand for investments in water drives the assessment process, and its implications in terms of resources use (water, land) is checked against available supply. The demand for investments in water varies according to the needs of the population. In order to capture this demand, the project has adopted a livelihood mapping approach.

Livelihood zones mapping and analysis divides the country into areas where rural people share relatively homogeneous living conditions that are based on a combination of biophysical and socio-economic determinants. It describes the rural population's main sources of livelihood (by category of people), their natural resources base, potential and key constraints to development. It analyses the relation between people and water and assists understanding of the extent and how water can be a factor in development.

The different steps of this methodology followed for national analysis are:

1. Mapping of the main livelihood zones, responding to the following questions:
   - What are the different farmer typologies and rural livelihood strategies?
   - What are the main water-related constraints and needs in the different rural livelihood contexts?
2. Mapping of the potential and opportunities for improving smallholders' livelihood through water interventions:
3. Estimation of the number and percentage of rural households that may benefit from AWM interventions.
4. Mapping of the suitability and demand for a series of specific AWM solutions, showing where they have the highest potential impact on rural livelihoods.
5. Estimation of the potential number of beneficiaries, the potential application area and total investment costs for each AWM solution in each livelihood zone.

FAO conducted and coordinated a participatory AWM mapping process in each project country in close collaboration with national partners. These products were developed using an approach that included national level data collection and processing, case study analysis and local consultation. The livelihood map was developed during a participatory mapping workshop, which gathered a large number of national experts from different fields (agriculture, water, social sciences, geography, etc.)

and institutions (government, universities, non-governmental organizations (NGOs), etc.) as well as farmers' groups. This process was organized in two phases:

- a first workshop established the basis for the analysis and started depiction of the relationships between rural livelihoods and AWM; and
- a second or series of events - both at national and regional levels – were designed to review the maps and refine the criteria used to define the potential for AWM and the suitability of different technologies.

The outputs of these consultations were enhanced using secondary data analysis from available national and subnational datasets, and statistics and further consultation with national and international experts.

Introduction

Insecure access to water for consumption and productive uses is a major constraint for rural people in sub-Saharan Africa (SSA) and India. For millions of smallholder farmers, fishers and herders in SSA, water is one of the most important production assets, and securing access to and control and management of water is key to enhancing their livelihoods (FAO and IFAD, 2008). Considering that agriculture remains the main source of living, development strategies need to focus on improving productivity in this sector.

Agricultural water is fundamental to agriculture-based rural livelihoods and sufficient availability and reliable access to water is commonly a constraint to production and other activities. In addition, water provides a centre around which other interventions can be organized. In this respect, increasing and improving investments in agricultural water management to support smallholders' livelihoods is still a priority in SSA and India.

Small-scale irrigation is very promising in developing countries; it can promote rural food security, poverty alleviation and adaptation to climate change. It enables households to generate more income, increase their resilience and, in some cases, transform their livelihoods (Tucker, 2010).

Nevertheless, investment decisions concerning AWM are frequently 'supply-driven', dictated by the availability of land and water resources and not by needs and priorities based on farmers' livelihoods. Indeed, the likelihood of the success of water-related investments depends on a more comprehensive analysis of dynamic opportunities and needs that are closely linked to biophysical and socio-economic contexts (FAO and IFAD, 2008).

Therefore, there is a need to develop new models of planning for AWM investments level, by recognizing the diversity and complexity of the country contexts and by tailoring interventions to rural population priorities and livelihood strategies. Any rural water development strategy will need to deal with multi-local diversified livelihood systems with limited capacities for agricultural investment, and a predominance of risk-avoiding strategies (IFAD, 2005). This means, "a fundamental shift beyond considering water as a resource for food production to focusing on people and the role water plays in their livelihood strategies" (WWAP, 2006); and implies a multiple-use perspective (Molden, 2007).

Starting with these considerations, this document presents a methodology that aims to identify AWM potential and opportunities in support of smallholders' livelihoods. Specifically, the methodology shows how livelihood mapping helps define locations where water constraints are a major factor affecting farmers and where specific agricultural water management and technologies can have a positive impact on smallholders' living conditions, particularly the poorest.

The primary goal of this approach is to define and assess the potential for scaling-up opportunities at the national level for AWM interventions in support of the livelihoods of smallholder farmers.

This report proposes a method for identifying the locations where water constraints are a major factor affecting smallholders' livelihoods and where agricultural water management in general, as well as specific technologies, can boost the poorest farmers' livelihoods. This present report builds on previous studies conducted by the FAO and IFAD (2008) and Sullivan *et al.* (2009).

The method described relies on a livelihood mapping approach that allows characterizing the main country livelihood zones geographically and the role of agricultural water access and management in each domain. The likelihood of a successful adoption of AWM options by smallholders varies according to the main sources of livelihood, dictated in large part by different biophysical and socio-economic determinants including agroclimatic conditions, natural resources endowment, socio-political and cultural context.

Understanding the geographical characterization of rural livelihoods and the distribution of the main rural population typologies helps in the design of intervention strategies to improve agricultural water management and increase both the resilience and productivity of agriculture, and more generally to boost agricultural incomes.

More specifically, the approach consists of four elements or steps:

- understanding the link between access to water, water use and rural livelihoods;
- defining where AWM is key to ensuring sustainable rural livelihoods and where it can make a difference;
- understanding how AWM can contribute effectively to boost living conditions in rural areas, identifying which technological options are the most promising, and where the most suitable conditions exist for their adoption;
- defining and locating the target beneficiaries of the proposed AWM approaches and understanding their main strategies and how they can benefit from AWM.

This approach has been implemented and tested in surveys conducted in Burkina Faso, Ethiopia, Ghana, Tanzania and Zambia, and in the states of Madhya Pradesh and West Bengal in India. In each country/state, a number of relevant AWM interventions were identified by desk studies and consultations with national experts.

Content of the CD-Rom

The report encloses a CD-ROM with additional information, as follows:

1. **Country investment briefs**
   The briefs are summary reports prepared for each project countries (Burkina Faso, Ethiopia, Ghana, the United Republic of Tanzania, Zambia, Madhya Pradesh and West Bengal States in India) that describe the results of the analysis at country level and present all the mapping outputs as well as figures regarding the investment potential.

2. **Mapping outputs[1] of the analysis of opportunities for AWM interventions**
   The maps presented include, for each country/state:
   i) Maps of livelihood zones
   ii) Maps of potential beneficiaries of AWM interventions
   iii) Maps of biophysical suitability by type of AWM intervention
   iv) Maps of livelihood-based demand by type of AWM intervention.

3. **Interactive computer tool for AWM scenario analysis (an example is provided for West Bengal State)**
   The tool is developed in MS Excel and allows the users to customize the map of potential beneficiaries of AWM interventions by changing the value of the perceived demand for AWM intervention in the different livelihood zones.

4. **Country livelihood zones analysis reports**
   These reports, prepared by national partners in each project country/state, provide an in-depth overview of the country-level livelihood context by describing the different livelihood zone profiles, their key characteristics as well as their water-livelihood implications.

[1] The GIS datasets and metadata are available and can be downloaded in the FAO Geonetwork portal: http://www.fao.org/geonetwork/srv/en/main.home

Scope of this report

This report is to present the methodology used for mapping and assessment of the potential for investments in agricultural water management at country level in support of rural livelihoods. More specifically, the approach aims to:

1. **Map and describe the main country livelihood contexts**
   This is the starting point of the approach. The intent is to identify, characterize and locate the key livelihood contexts to better understand their main constraints and development needs their different farmer typologies and the implications for AWM.

2. **Map the AWM potential to improve smallholders' livelihoods**
   The purpose is to assess the entry point for AWM so as to improve rural livelihoods and, more specifically, identify where to prioritize investments in AWM in order to have the maximum impact on rural livelihoods.

3. **Map the suitability domains of specific AWM solutions**
   The purpose is to assess and map the area identified as the most promising for AWM technologies and investment options so as to generate the highest impact on smallholders' livelihoods. Specifically, the intent is to define and locate geographical domains where a given AWM technology or solution will result in highest benefits for livelihoods and where there is more likelihood for its adoption by smallholder farmers.

4. **Estimate the potential number of beneficiaries and costs of investing in AWM**
   On the basis of the geographical domains of the different AWM investment options, the approach foresees the estimation of the number of potential beneficiaries and application area as well as the potential investment costs at national level.

Concepts and definitions

The livelihoods perspective

The livelihoods perspective is an approach to determining how people make a living. It incorporates an understanding of how household capabilities, assets, and activities combine within a specified environment to achieve household well-being in the short and long term. Livelihoods analysis assesses the resilience of household strategies in the face of shocks and stresses, and assists in identifying vulnerable areas or groups. The findings generated provide a useful framework for supporting households in improving their living conditions and enhances their resilience to both external (e.g. drought) and internal threats (e.g. family illness) (FAO and IFAD, 2008).

According to Chambers and Conway (1992), livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living. It comprises the adequate stocks and flows of food and cash required to meet basic needs. It is made up of a range of farm and off-farm activities that together provide a variety of sources of procurement for food and cash. Thus each household can have several possible sources of entitlement that constitute its livelihood. These entitlements are based on the endowments of a household, and its position in the legal, political and social fabric of society. A livelihood is sustainable when it: i) can cope with and recover from stress and shocks that determine vulnerability; ii) maintain or enhance its capabilities and assets; and iii) provide sustainable livelihood opportunities for the next generation.

The vulnerability context refers to seasonality, trends, and shocks that affect people's livelihoods. The key attribute of these factors is that they are not susceptible to control by local people themselves, at least in the short and medium term (DFID, 2000).

Livelihood strategies vary significantly within a country, from rural to urban areas, and across countries. The household is taken as the unit of reference because it is the primary level of aggregation through which people organize production, share income and consumption (FAO, 2006a).

Policies and institutions that influence rural household's access to livelihood assets are also important aspects of the livelihood framework (DFID, 2000). Institutions are the social cement linking stakeholders to access to capital of different kinds to the means of exercising power and so define the gateways through which they pass on the route to positive or negative [livelihood] adaptation (Scoones, 1998).

Mapping rural livelihoods

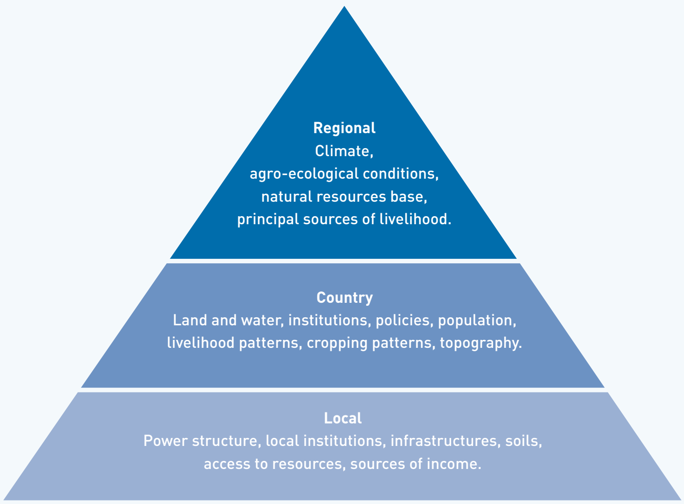
Provided that patterns of rural livelihood vary from one area to another, based on local factors such as climate, soil or access to markets, livelihood mapping consists of identifying and mapping areas with relatively homogeneous conditions, where households share similar livelihood patterns and have relatively similar entitlements, which are formed by considering both biophysical and socio-economic determinants. In this case, specific attention is given to the use and management of rural water resources. The analysis, therefore, delineates geographical zones within which people share similar livelihood patterns, such as source of income, access to food, farming practices, including crops, livestock and access to markets.

Different livelihood options are available to people depending on where they live (the agro-ecological context) and the resources to which they have access (land, infrastructure, assets, financial resources, labour, social network, etc.). The possibilities are many but not unlimited; in practice, the range of options is typically limited. People produce food, they exchange goods or services for food, or they earn cash with which they can buy food. Once it is evident that a group of people in a certain area share a predominant way of securing their food, then it is possible to characterize the area in terms of the dominant economic activity: a maize-based farming zone, or pastoral zone based on camel raising (USAID, 2008).

It is important to recognize that mapping livelihoods at different scales uses different criteria and parameters. Livelihoods are characterized at the regional level differently than at country or local levels. For example, at the regional level, given the heterogeneity of large-scale conditions, livelihood mapping in rural areas will be based predominantly on the agro-climatic conditions that dictate major farming practices, while such a scale will make it difficult to account for the variety of socio-economic conditions that influence livelihoods locally. Scaling down to the country and local levels, such socio-economic conditions, together with political and institutional parameters, can better take into account the delineation of domains of homogenous livelihoods (FAO and IFAD, 2008).

Figure 1 shows the different variables at different scales that allow the identification, mapping and characterizing of homogeneous livelihood zones.

Figure 1 Rural livelihood determinants at different scales (FAO and IFAD, 2008)



Most livelihoods are complex and are shaped by a wide-range of factors. Generally, four primary categories of determinants can be identified: i) Geography climate and natural resources; ii) Production; iii) Market and Infrastructure; iv) Socio-economic patters. In addition, as the approach aims at determining relationship and interaction between livelihoods and water resources, it is necessary to add a fifth determinant: access to water resources.

i. **Geography climate and natural resources**
These variables correspond to natural capital in the sustainable livelihood framework (DFID, 2000) and represent natural resources available to people and the way they are used and the prevailing agroclimatic conditions that influence farming activities. People living in a fertile highland area have very different options than those living in a semi-arid lowland area. The most important natural factors are topography (i.e. the physical features of an area, including the relief, coasts, rivers, and plains), soil, climate (i.e. temperature and rainfall) and vegetation. These are the variables that most influence the typology of production activities and the livelihood strategies.

ii. **Production**

There are several types of rural production system. Most can be grouped into a few main categories: agricultural; agro-pastoral; pastoral; fishing; hunting-gathering and, in some cases, other systems (e.g. labour-based, mining areas, game reserves, etc.). The system of production is determined by several factors, of which geography, climate and natural resources are clearly the most significant. Other factors that influence production patterns are markets and infrastructure as well as the socio-economic context.

Table 1 Sources of rural livelihoods associated with major production systems (adapted from FEG consulting)

Sources of rural livelihood	Main characteristics	Additional notes
Agriculture	Example of main types of Agricultural Livelihood zones • Rainfed and/or irrigated • Food crop and/or cash crop • Crop surplus or crop deficit • Hand and/or animal/mechanical • traction • Short or long rains dependent • Lowland - highland - mid-highland • High/low potential • In/Fertile soils • Sparsely or densely populated	In this type of zone, the main activity is crop production, typically supplemented by livestock keeping but on a small scale (e.g. 1-2 dairy cattle and poultry for most households). We want to rank the main crops consumed and the main crops sold.
Pastoral	Agro-ecological zone	Pastoral livelihoods are those where the core or main activity is the raising of livestock. We want to rank the main types of livestock based on their importance to household food and income.
Agro-pastoral	*Crops more/less important than Livestock* Plus any agricultural or pastoral characteristics	Agro-pastoralists both herd livestock and grow crops.
Fishing	Boats, nets and/or lines	source of income.
Labour-based	Plantation - ranch - urban Local work - seasonal - long-term migration Type of plantation (tea, coffee, etc.)	In this type of zone the majority of people derive their income from labour and purchase most of their food
Hunter-gatherer	Hunting of animals more/less important than gathering of wild plants	Hunter-gatherers derive a substantial proportion of their food from hunting and gathering (not just income, as for pastoralists that may collect and sell charcoal, for example.)
trading	Indicate main characteristics	pattern not listed above.

iii. **Market and infrastructure**

The most important human-made factors are those related to infrastructure (roads, railways, and telecommunications). People living along major roads may have better access to markets, food and income options than those living in more remote areas. We can think of these three factors as linked to consumption as follows: geography affects both the options for production (climate, soil, etc.) and for marketing/trade (roads, proximity to urban centres, etc.), which in turn affect household consumption. Household production (of food and other items) may either be directly consumed or may be traded/exchanged for other items in the market. Consumption is critically determined by what is available in these markets, and how people obtain the means to purchase these commodities.

iv. Socio-economic patterns
The socio-economic context is a crucial element to describe livelihoods, although socio-economic criteria can hardly be mapped. These elements are often defined by targeted surveys and the use of subnational statistics. Examples of socio-economic criteria are: population density and distribution, farmers' typology, average landholding size, vulnerability to climate shocks, access to credit, etc.

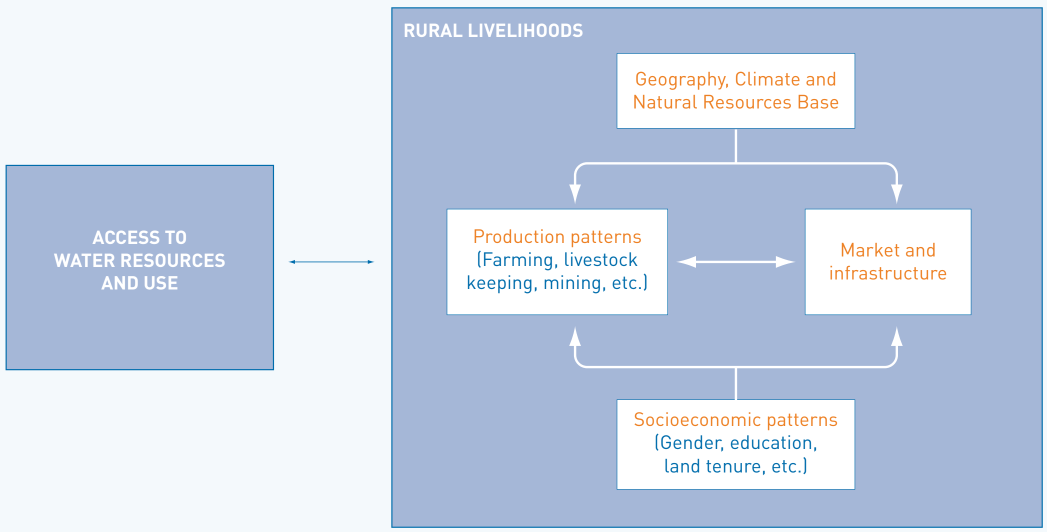
v. Access to water resources
The main focus of this analysis is to understand the implications and linkages between water resources and rural livelihoods. As the main objective of this approach is to provide clear recommendations for AWM interventions in support of livelihoods, these aspects are then crucially important to the definition of the livelihood zones boundaries and description and are key livelihood determinants for the mapping process.

Mapping livelihood zones is a challenge as not all livelihood determinants can be mapped, represented or are relevant at all scales. Mapping livelihoods at national level entails an effort that captures the most distinguishing characteristics of the zones, while avoiding over-approximation. This process is particularly challenging in contexts where statistical and spatial datasets are not available or have significant gaps, particularly in sub-Saharan Africa (SSA).

Livelihood zone mapping involves more than just the drawing of maps. A livelihood zone map is of little use unless it is accompanied by a detailed description of the patterns of livelihoods in each zone, and ideally by an analysis of the underlying reasons for differences between zones. This means analysing in some detail the production and trade/exchange options in each of the zones and the influence that the underlying geography has on each (FEG, 2011).

Most livelihoods are complex, and are shaped by a wide-range of factors. Generally, when defining livelihood zones we look at four primary factors (Figure 2):

Figure 2 Rural livelihoods determinants



Summary of methodology

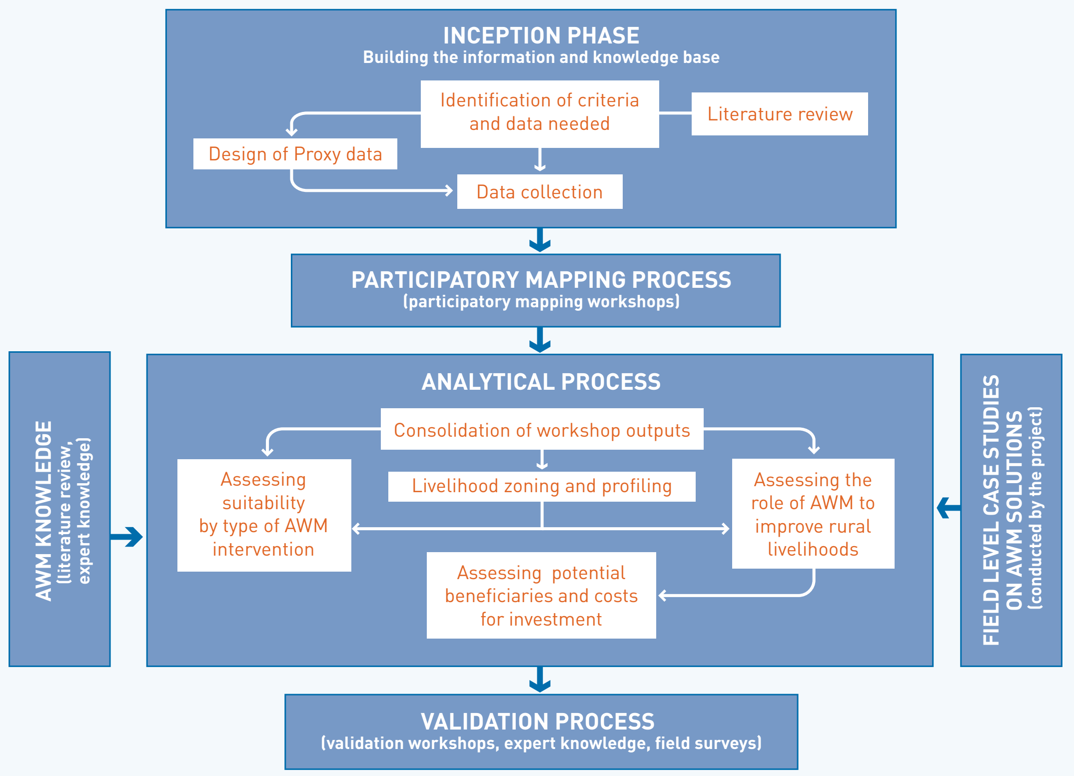
The method is characterized by different phases to be implemented over a period between 3 and 6 months, depending on the complexity and size of the country. The approach foresees a balance between desk analytical work, field-level data collection and participatory consultations with national experts and stakeholders.

Specifically, the approach is characterized by:

1. An inception phase to define the mapping criteria and data needed for the analysis and to build the information and knowledge base as well as to conduct the data and information collection process
2. A participatory mapping phase to interpret the data and information collected and start depicting livelihood zones, AWM investment potential and suitability domains for AWM solutions
3. A data and information-processing phase to consolidate and fully describe the map of livelihood zones and assess the AWM investment priorities, geographical domains for AWM solutions and estimate and quantify the potential beneficiaries of AWM solutions.
4. A validation phase that is characterized by participatory validation workshops as well as the data check and comparison using surveys, studies and field sample.

Figure 3 shows the framework of the method proposed.

Figure 3 Framework methodology



Participatory consultations

Livelihood mapping is a complex concept that requires a deep knowledge of the country context and the capacity to integrate and interpret different typologies and sources of information. To cope with this complexity, and given that relevant data and statistics are often lacking, the analysis builds significantly on expert knowledge by involving national and local stakeholders. To best capitalize on expert knowledge, workshops have been designed and conducted in all the project countries. Adopting a participatory mapping approach, the purpose of the workshop is to establish the basis of the analysis and start depicting the relationships between rural livelihoods and AWM, trying understanding the main constraints to development and to define the role of AWM in improving livelihoods. This process is organized in two phases:

i. Participatory mapping process: the purpose of a first workshop is to set up the basis for the analysis and begin depicting the relationships between rural livelihoods and AWM. The participatory mapping process is fully described under the heading: *Participatory mapping process*.
i. Participatory validation process: a second workshop or series of events is organized – both at national and regional levels – to review the maps and refine the criteria used to define the potential for AWM and the suitability of different technologies. The participatory validation process is fully described under *Validation process*.

The workshops gather a group of national/local experts from different fields (agriculture, social sciences, geography, etc.) and diverse institutions from the public and private sectors as well as representatives of civil society. They also gather representatives from the different regions to ensure full knowledge of livelihood aspects throughout the country and to ensure local ownership of the mapping process. When possible, discussions were held at regional level to get closer to ground realities.

The workshop is an important link between the assessment of the AWM context and the livelihood analysis as it allows practitioners to relate the proposed AWM solutions to the livelihood context and to initiate defining and mapping suitability domains for AWM solutions on the basis of the livelihood patterns.

Inception phase: building the data and information base

Literature review, identification of mapping criteria and data needed

The first step of the methodology is to conduct a literature review of existing information at global, regional and country level on rural livelihoods and their implication for water resources. In particular the review should focus on literature based on various methodologies and approaches concerning livelihood-zone mapping and water intervention identification available inside and outside the region. In addition, the review should entail an assessment of the availability of regional and national data and information, against the requirements for livelihood-zone mapping and description, and identification of water interventions.

Another important step in this approach is to identify the mapping criteria to feed the Geographic Information System (GIS) environment and characterize livelihoods zones and the AWM potential for poverty reduction.

The aim is to identify the key biophysical and socio-economic determinants that best represent a certain livelihood and AWM context. More precisely, the determinants would allow definition of the boundaries of the different livelihood domains and describe their main livelihood characteristics.

The determinants selected can be organized into the four different categories (Table 2) that characterize livelihoods:

- geography, climate and natural resources base;
- production patterns;
- market and infrastructures;
- socio-economic patterns.

Table 2 Examples of livelihood determinants

Geography, natural resources base and climate	Production patterns	Infrastructures	Socio-economic patterns
Landcover patterns	Crop distribution and intensity	Access to markets	Rural population density
Agro-ecological zones	Livestock distribution	Roads and railroads	Rural poverty rates
Topography		Water infrastructure	Average landholding size
Rainfall pattern		Mines	
Groundwater levels		Access to credit institutions	

In principle, variables and layers that already represent a natural delineation, boundary or pattern (e.g. agro-ecological zones, cropping patterns, landcover, topography, population density, etc.) are used to define livelihood domains boundaries while others, particularly the aggregated statistics, are used to describe and enrich livelihood domains. Depending on the focus and purpose of livelihood mapping (monitoring food security, emergency and relief interventions, water-related investments, etc.), the baseline delineation could start with different layers.

The livelihood criteria are defined in each country in consultation with the local partner following the general framework. Depending on the country, in many cases the agro-climatic determinants are the main drivers that determine livelihood patterns, while in other cases production and cropping patterns may be more prominent. These drivers are generally the base layer and delineation of livelihood domains.

In Annex 1 a comprehensive table is presented showing the criteria framework and depicting the complexity of information defining livelihood patterns in different countries. The table can be considered as a general baseline framework to help in the identification and collection of data in the different countries. Not all the criteria listed can be translated into spatially explicit variables and many of them, although they can be mapped, may not be available in all countries.

One challenge of drawing livelihood maps is how to combine continuous variables (typically agro-ecological variables such as rainfall, temperature, topography, or population density, etc.), with socio-economic data, which is usually available (in the form of statistics) from some level of administrative boundaries.

In a few cases, agro-climatic conditions play an important role and are the main factors used in mapping livelihood zones. This is typical for countries where there are clearly contrasting climatic conditions and where the rural population's livelihoods are driven mostly by agricultural practices. In other cases, market or other socio-economic conditions may be the main determinants used to describe livelihood.

Data collection

The type of data used in the analysis is diverse and available at different scales and from different sources. The data collected can be organized as follows:

- **Global and regional level datasets**
  Certain categories of global datasets, particularly the biophysical, have reached a high level of detail and resolution and can be used for national level analyses. This is the case of climatic datasets (e.g. rainfall, temperature, aridity index, length of growing period, topography, infrastructure (e.g. roads and railroads), as well as some socio-economic data (e.g. population distribution).
- **National level datasets**
  Some key determinants are very much scale-dependent and, although they can be available at regional and global level, it is preferable to obtain national level datasets that can capture details and diversity. These are for instance: land cover/land use patterns, river network, cropping patterns and distribution, livestock distribution, soils and others. The analysis shows that, while it would be preferable to have access to national level datasets for all data, in most cases these datasets are not available or not accessible at national level. Clearly, there is a gap in capacity between well-established and funded global datasets and much poorer GIS data production capacity and dissemination strategy at national level.
- **Subnational statistics (cropping patterns, landholding, etc.)**
  This type of information is very important and its availability varies from country-to-country. The critical aspect is the size of the administrative units and at which subnational level the information is available. If the sub-national units (e.g. districts, blocks, etc.) are small and, as a consequence, the information is sufficiently disaggregated, these data can be relatively easily included in the GIS analysis and can contribute to the delineation and description of livelihood zones. The common subnational statistics used in a typical analysis are: crop production and area, livestock production, level of mechanization, irrigation typology, land-holding size, poverty etc.

- **Expert knowledge: National and local surveys, interviews and participatory consultations** To cope with the complexity of the information needed and the limited availability of data, the analysis makes use of expert knowledge to be used as qualitative information to complement the existing data. This knowledge is also used to interpret the data. The following sections describe in more detail the participatory mapping workshops that are the main source of experts' information.

See Annex 2 for a detailed list of data used in the analysis.

Use of proxy data

Specific data are important for the analysis both regarding the characterization of the livelihood context and to spatially characterize the potential for specific AWM interventions. However, in many countries, these data are not available, and can only be represented by proxy data that best characterizes the information required. In particular, proxies have been used to define:

i. **Shallow groundwater potential**
Information on the existence and distribution of shallow groundwater (to a depth of 10 m) is important in the assessment of the potential for small-scale water management. It is, however, very scarce, inaccurate and scattered, particularly in SSA where shallow aquifers are usually small and highly dispersed. In this study, soil maps have been used as a data proxy to ascertain the potential existence of shallow aquifers. Shallow aquifers have been associated with the presence of specific soil types, specifically Fluvisols, Gleyisols and Gleyic subunits.

Soil Mapping Units from the Harmonized World Soil Database 2009 (IIASA and FAO, 2009) have been classified, based on the occurrence of these soils. Non-vegetated areas derived from Global Landcover 2000 (IES, 2000) dataset have been used to mask out areas where the absence of vegetation is considered to be an indicator of the lack of water for plant–root systems. Field samples, when available, and expert knowledge have helped refine the maps obtained. An example of a map is shown in Figure 4:

ii. **Rural poverty**
The level and dimensions of poverty are important in an analysis that claims to support poverty reduction and it is therefore important to be able to map both the prevalence and absolute number of rural poor. The analysis has adopted rural child malnutrition – more specifically prevalence of underweight among children under five-years of age – as a measure of rural poverty. Child malnutrition represents a good proxy for rural poverty and food insecurity (Setboonsarng, 2005). It is widely accepted that high rates of child malnutrition are found in areas with chronic widespread poverty (ADB, 2001). Although an income-based or expenditure-based measure of poverty remains an important indicator, nutrition-based measures were deemed more appropriate for the analysis in Ethiopia and the other countries. Figure 5 shows an example of a rural poverty map.

Figure 4 Assessing shallow groundwater potential in Ethiopia from soil and land cover data

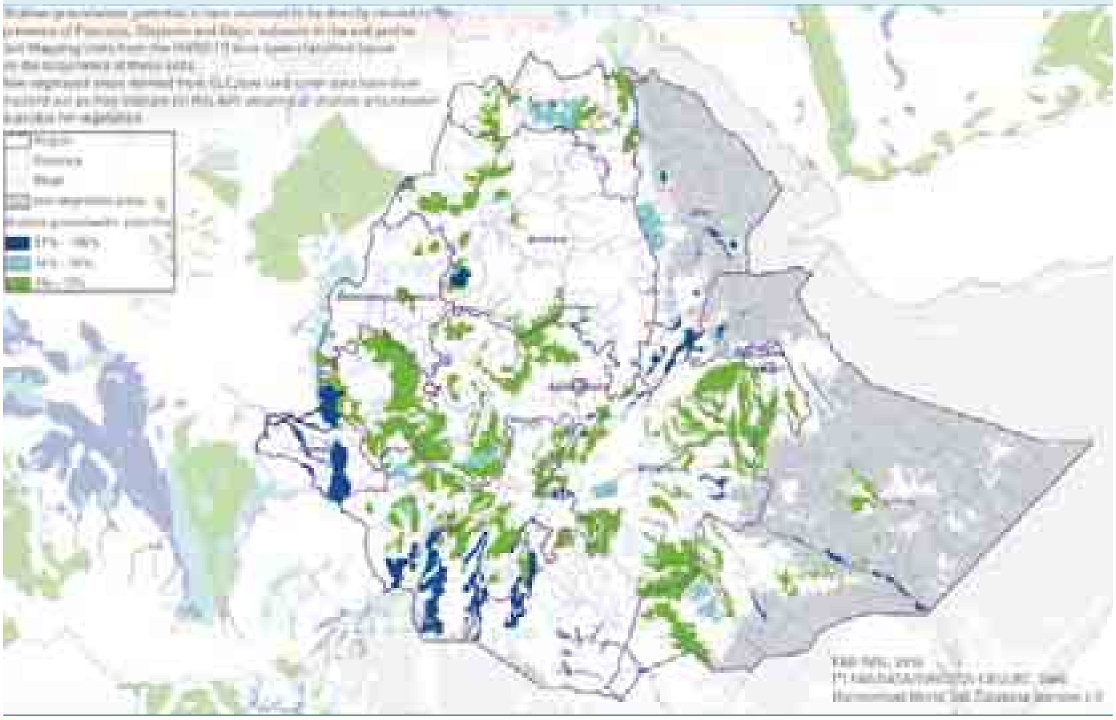
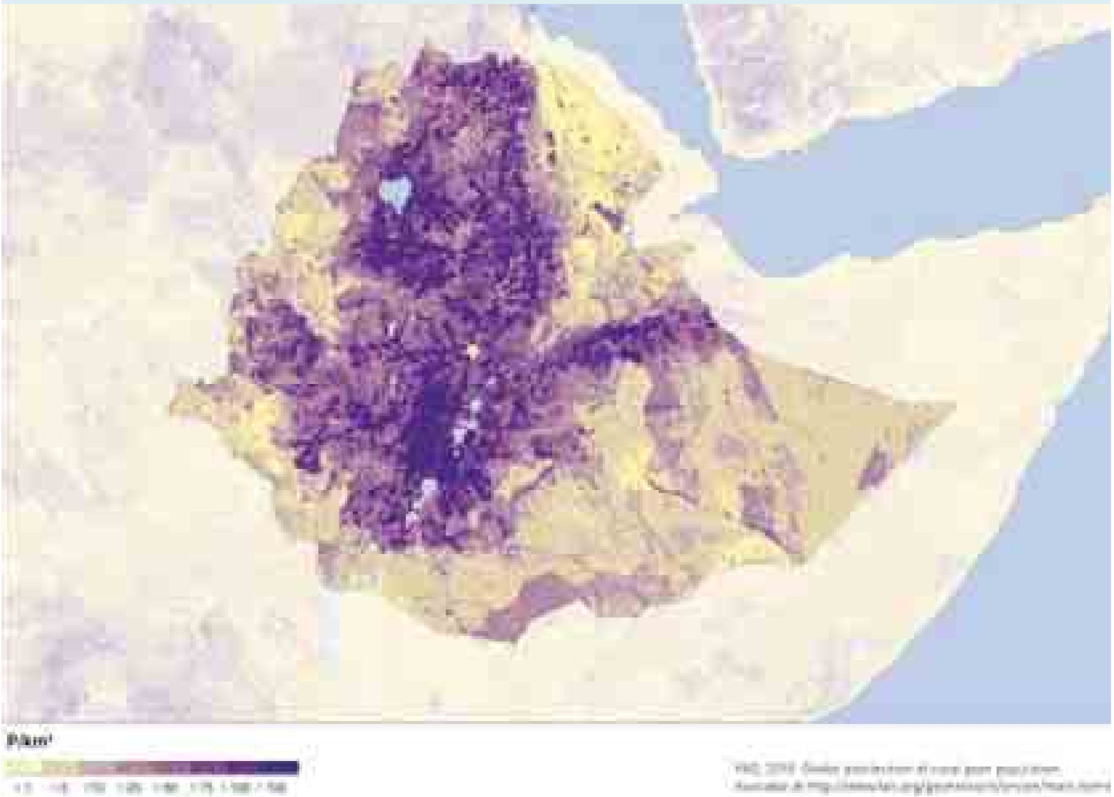


Figure 5 Rural poverty in Ethiopia



Mapping and analytical process

Participatory mapping process

The objective of the participatory workshop is to map and describe the socio-economic and biophysical context where AWM-related activities are in place, and more specifically, to define links between water, rural poverty and livelihoods and show how access to agricultural water is directly related to rural livelihoods.

The workshops are organized to combine and alternate participatory working groups with plenary sessions in order to maintain a high level of interaction and to ensure active contribution and brainstorming by the participants. The workshop is structured into three main participatory phases made up of both a working group and plenary sessions.

Preparation of a national livelihood zones map

The participants are divided into working groups, each cover a specific part of the country. Each working group would:

i. define the main drivers characterizing livelihoods in the country;

ii. delineate the boundaries of the main zones based on the key drivers;

Figure 6 Output of participatory mapping in Zambia

iii. preparation of a map attribute table that describes the key characteristics and their implication for water resources in each of the livelihood zones. In each zone identified define, describe and quantify (when possible):

- main general characteristics (e.g. agro-climatic conditions, cropping patterns, livestock, population and gender, etc.);
- water and AWM related aspects (e.g. source of water, groundwater availability, level of AWM development, etc.);

- main constraints and priorities in the different livelihood contexts (e.g. access to markets, lack of water, extension services, etc.); and
- main water-related constraints (e.g. lack of rainfall, groundwater contamination, conflicts among users, etc.)

iv. identification and quantification of main farmer typologies and other rural population categories (see Box 1.)

The participants are then gathered in a plenary session to discuss the respective groups' outputs and to integrate the results in order to synthesize the different local maps into a national map.

The number and size of the livelihood zones depends very much on the country. In principle, the number should not exceed 20 livelihood zones; otherwise maps become unworkable and misleading. The maps

Box 1 Rural population typology in West Bengal

The identification and quantification of a typology of rural population is a crucial aspect in the analysis. These typologies have different characteristics, constraints, priorities and attitudes for which different AWM approaches and solutions can impact differently on their livelihoods. An example of the distribution of rural population typologies in the different livelihood zones in West Bengal is described below. Main typologies of rural population:

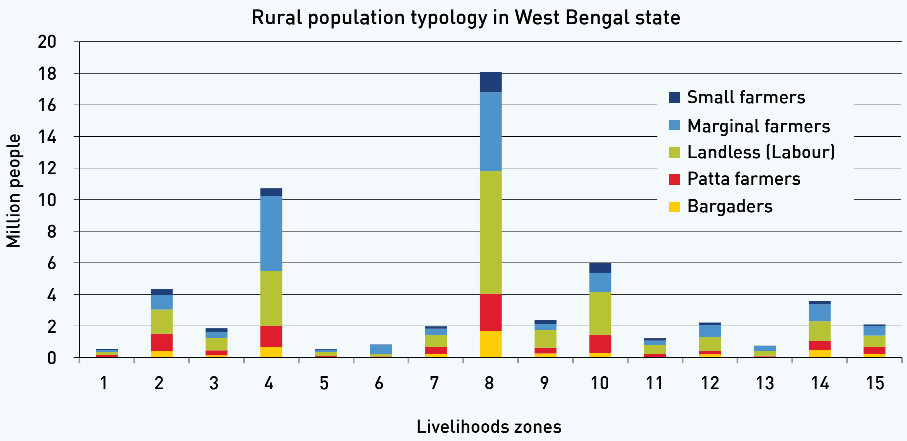
Patta-holders – *Patta* is the word used to describe agricultural land donated by the State Government to landless families. *Patta*-holders are landless farmers that have received this land from the State. The *Patta*-holders own the land title.

Bargadars – are in the category of permanent sharecroppers. They cultivate land owned by others and the produce is divided into three equal parts. Two-thirds of the total production is given to the *Bargadar* and one-third to the landowner. Out of the two-thirds portion received by the *bargadar*, 50 percent is for land maintenance and the remaining is considered his or her income. The owner can never sell or lease out that particular piece of land without the consent of the *bargadar* and the *bargadar* can never own the land.

Landless farmers – do not possess land, and depend on land owned by others for cultivation by providing their labour.

Marginal farmers – have land holdings of 1 ha or less (2.5 acres).

Small-scale farmers – have land holdings of 2 ha (5 acres) or less.



should help visualize problems and solutions and should provide baseline information for decision-making. The idea is to try to capture the diversity of livelihoods, but a certain degree of generalization should be accepted. However the biophysical factors (climate, topography, etc.) are the major drivers for mapping and the number of zones depends on the complexity and diversity of these factors.

The main output is a preliminary sketch of the country livelihood zone map, including an attribute table describing the different livelihood zones.

Preliminary identification of priority areas for AWM interventions and investments

Using the livelihood map as the base layer and for information, this phase aims to assess where to prioritize AWM investments to improve rural livelihoods. This step is crucial for capturing the experts' perspective of the role of water in support of rural livelihoods.

In plenary session, the participants discuss the key factors and aspects that determine the priority for AWM intervention to improve smallholders' livelihoods. The scope is to assess the role and relevance of AWM and the entry point for improving livelihoods. Consecutively, working groups are organized and the relevance of the different factors identified assessed in relation to the different livelihood zones. Each group works on different livelihood zones.

Specifically, this phase aims to define:

i. **Who** are the target beneficiaries and where are they mostly concentrated?
   - Which categories of livelihoods and farmers can most benefit from water interventions?

ii. **Where**, based on the type of livelihoods, is the rural population most dependent on water availability and where are they more vulnerable to fluctuations in its availability?

Identify main AWM options and assessment of their importance in each zone

Similar to the previous phase, the aim is to identify the most promising AWM options that best suit the different livelihood contexts. Starting with the AWM solutions studied in the case studies conducted during the project, this phase analyses their relevance to the main AWM options in the different livelihood zones.

In addition, the workshop provides an opportunity for collecting and identifying sources of datasets and statistics necessary for the overall assessment.

Processing and consolidation of workshop outputs: integrating quantitative and qualitative information

The main output of the participatory mapping workshop and the data processing is the country map of livelihood zones, which forms the basis for the overall assessment. This map characterizes the country by delineating a number of 10-20 livelihood zones – depending on the heterogeneity and size of the country – that represent different livelihood contexts. The map is accompanied by a detailed legend and a profiling that describes and highlights the key aspects of each zone, including the description of the typologies of farming population.

In different countries where the analysis has been conducted, the livelihood zones maps developed by FEWS NET [2] have been used as baseline to start the participatory mapping process or to consolidate

[2] The Famine Early Warning Systems Network (FEWS NET) is a USAID-funded activity that collaborates with international, regional and national partners to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues. FEWS NET professionals in the Africa, Central America, Haiti, Afghanistan and the United States monitor and analyze relevant data and information in terms of its impacts on livelihoods and markets to identify potential threats to food security.

the preliminary mapping outputs from the participatory workshops. The FEWS NET maps have been designed specifically to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues. Therefore, given the focus of this analysis on AWM, in some cases the maps have been slightly modified to better represent water-livelihoods implications.

Consolidation of the livelihood zone map

A significant challenge for participatory methods is the integration of qualitative information and quantitative data. Focus group discussions and key informant consultations provide essential insights into indicators that are otherwise difficult to capture, either for their sensitivity (gender or ethnic issues) or for lack of publicly available data (groundwater use or quality, detailed cropping pattern maps, access to credit etc.).

Nevertheless, this wealth of information needs to be cross-checked to reduce subjectivity and entailed in a methodology that is replicable over space and time.

The first important step in the validation process occurs within the workshop itself, during the consolidation process of working groups' discussion into one collective output. Plenary discussion of groups' findings highlights areas of uncertainty that need further investigation and justification by referring to objective data.

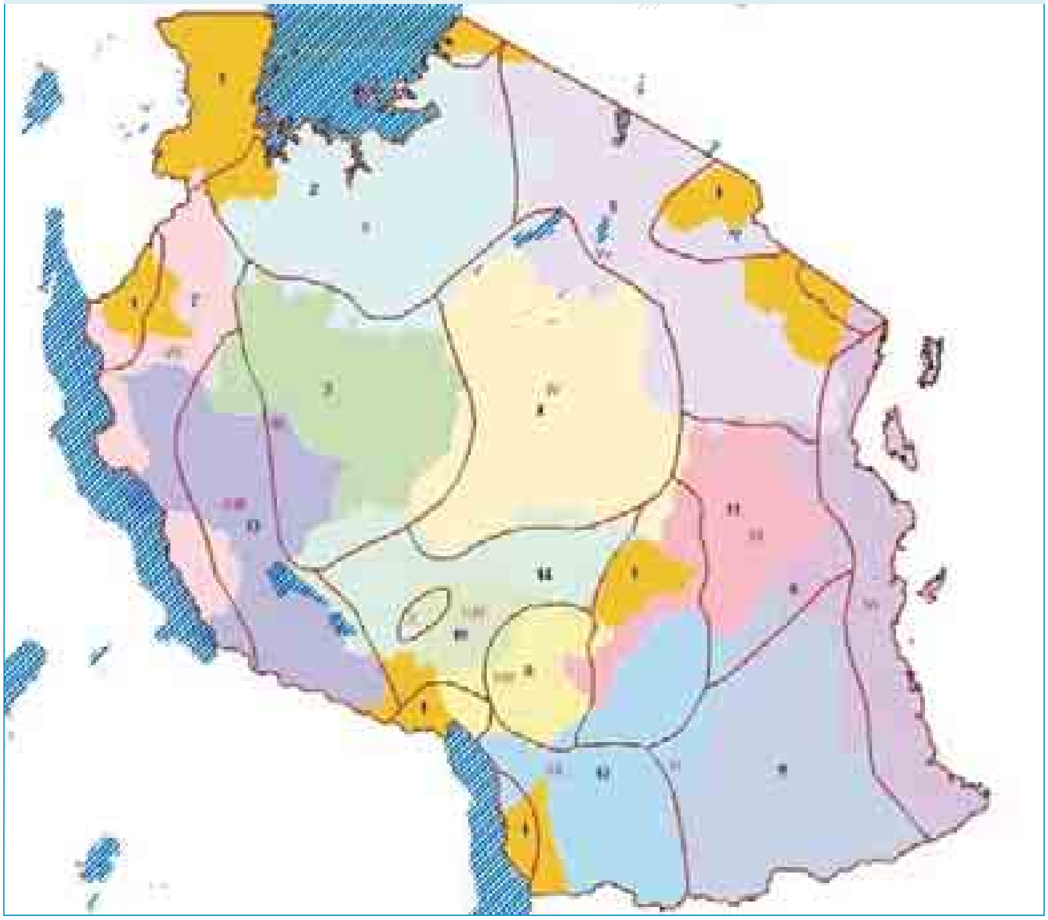
Secondary data analysis and comparison with workshops outputs is the core of the 'desktop validation' process, which includes, in most cases, a new delineation of livelihood zone boundaries.

Ideally, livelihood zone boundaries would coincide with administrative boundaries, but this is not always possible because the main determinants of the livelihood zones rarely follow administrative boundaries. A single district may well contain more than one agro-ecological division or other elements that have a major effect on livelihoods – there may be two livelihood zones within the same district. These zones, however, are likely to extend beyond the district, so that the geography of the livelihoods and administrative zones do not necessarily coincide.

Yet, combination with existing administrative boundaries is important for two main reasons. First, it makes it simpler to use statistical data (available from administrative units) to describe the livelihood zone. Second, administrative boundaries are well known by most stakeholders, including planners, local managers and decision-makers, and the results of the livelihood analysis are therefore easier to understand than if a new division of the country's territory is proposed.

Therefore, the new delineation should build, as far as possible, on aggregation of lowest level administrative units to: i) take advantage of the link with census and statistical data; ii) facilitate targeting and institutional responses; and iii) make reference to geographic units that are easily recognized at the local level. Preferably, livelihood zone boundaries would coincide with administrative boundaries, but not always. In practice, homogenous agro-ecological and socio-economic zones often cross larger administrative units. In these cases the delineation is based on other criteria that better capture the delineation between different livelihoods patterns (topography, climatic data, land cover data, etc.). See example for Tanzania in Figure 7.

Figure 7 Example of workshop map processing: matching livelihood zones with existing natural and administrative boundaries (Tanzania)



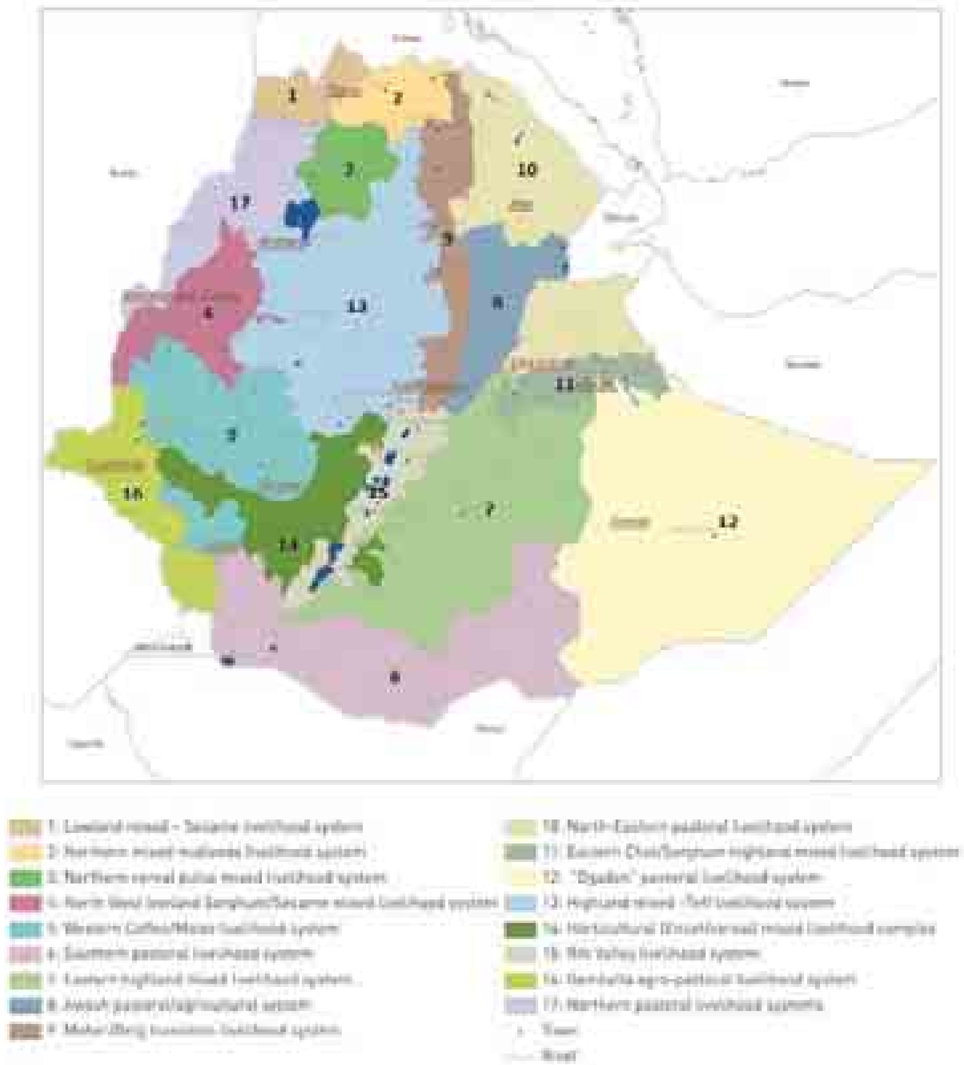
Example of a workshop attributes table of livelihood zones, and corresponding dataset used for consolidation (see Table 3).

Table 3 Example of workshop map processing: using existing datasets to consolidate attributes of livelihood zones (Zambia)

National Workshop outcomes					Consolidation input
Livelihood zone	**Description**	**Livelihood sources**	**Rural population density**	**AEZ region**	**Main GIS layers used in consolidating boundaries of zones**
1	Grassland area with (vulnerable) small-scale farmers with cassava, sorghum, cattle and timber	Cattle, millet, sorghum, tourism, timber	Low	1	Land cover (grassland), rainfall, length of growing period, agricultural production statistics
2	Agricultural area with smallholder with high-productivity maize	Tourism, sorghum, timber, vegetables, cattle	High	1	Land cover (agricultural classes), agricultural production statistics
3	Forested area with game management reserves, game hunting or tourism activities (including Livingstone area); smallholder may benefit from employment but have restricted access to reserve	Tourism, poaching, hunting	Low		World Database on Protected Areas
...	...	...	...	...	...

The final product of this process is a map of livelihood zones with their accompanying attributes aggregated at the level of the livelihood zone (Figure 8 and Table 4).

Figure 8 Map of livelihood zones, Ethiopia



Another possible approach – which has been tested in some countries but clarity of outputs needs to be improved – is to use statistical clustering (Principal Component Analysis and non-hierarchical clustering) of administrative units to obtain associations of relatively homogeneous units with regards to the indicators identified during the livelihood workshop.

Consolidation of the map legend

The map legend represents the base that facilitates reading and understanding the content of the map. During the participatory mapping phase a preliminary legend is developed in a participatory manner. The post-workshop phase is crucial for consolidating the legend on the basis of the attribute table. The legend should capture the key dominant characteristics of each zone that can provide an idea of the main drivers determining the livelihoods of rural people. The drivers can encompass the agro-ecological conditions (e.g. semi-arid, humid), topography (e.g. highlands, lowlands, valley), the

Table 4 Attribute table for livelihood zones map of Ethiopia

Zone	Key livelihood aspects	Main farmer typology	Rural Population	Poverty rate	Main constraints to development	To what extent livelihoods depend on water	AWM potential for improving livelihoods
1	Lowland cereal mixed (unimodal semiarid cereal-livestock production)	Commercial farmers and emerging smallholders	521 846	Moderate	Water shortage, erratic rainfall, economic & social infrastructure	Low	Low
2	Highland mixed farming (sub-humid cereal-vegetables production)	Traditional smallholders and landless	2 397 100	High	Shortage of cultivable land, shortage of agricultural water	Moderate	Moderate
3	Sub afro-alpine system (barley-sheep)	Traditional smallholders and landless	2 194 430	High	Shortage of cultivable land, erratic rainfall, poor infrastructure	Moderate	Moderate-high
4	Humid lowland mixed (crop-livestock production)	Traditional and highly vulnerable smallholders	729 092	Moderate	Land ownership, market access	Moderate	Moderate-high
5	Forest coffee-based system	Traditional smallholders	7 261 760	Moderate	Shortage of cultivable land, erratic rainfall, shortage of agricultural water	Moderate	High
6	Southern pastoral system	Traditional and emerging smallholders	1 601 320	Moderate	Erratic rainfall, poor infrastructure, access to market and roads	Moderate-high	Moderate-high
7	Highland temperate mixed	Traditional smallholders and commercial farmers	7 371 010	Low	Shortage of cultivable land, erratic rainfall poor infrastructure	Moderate-high	Moderate-high
8	Arid and Semiarid lowlands (pastoralism)	Pastoralists and emerging stallholders	889 473	High	Flooding, salinity, social and ethnic issues (nomads)	High	Moderate
9	Unimodal highland mixed system	Traditional and highly vulnerable smallholders	4 318 230	Moderate	Shortage of grazing land, erratic rainfall, poor infrastructure	Moderate-high	Moderate
10	Arid (small ruminants, camels)	Highly vulnerable pastoralists	814 277	High	Harsh climate, salinity, volcanic soil, access to market	High	Low
11	Semiarid highlands commercial agriculture	Traditional smallholders and commercial farmers	3 808 710	Moderate	Land scarcity, soil degradation	High	High

Table 4 (continued)

Zone	Key livelihood aspects	Main farmer typology	Rural Population	Poverty rate	Main constraints to development	To what extent livelihoods depend on water	AWM potential for improving livelihoods
12	Arid	Highly vulnerable pastoralists	2 612 240	High	Water scarcity, insecurity	High	Low
13	Highlands humid rainfed system	Traditional smallholders	17 294 000	High	Land scarcity, degradation	Moderate-high	High
14	Enset complex (horticulture and enset production)	Traditional smallholders	9 166 120	High	Rainfall, traditional agricultural system, high population density	Moderate	Moderate-high
15	Semiarid Rift Valley (vegetable and livestock)	Traditional smallholders	5 390 900	High	Drought hazards, poor soil fertility, water quality	High	High
16	Western agropastoral system	Traditional smallholders and pastoralists	469 540	Moderate	Erratic rainfall and poor infrastructure	Moderate-high	High
17	Agropastoral trading system	Traditional smallholders and pastoralists	950 782	High	Rainfall, market access, illegal trade	Low	Moderate

production patterns (e.g. agropastoral, commercial farming, fishing, mining, etc.), cropping patterns (e.g. maize-based, rice-maize based, etc.), geographical features (coastal zones, peri-urban, lake, etc.), other specific country geographical features (e.g. Lake Tanganyika, Rift Valley, etc.) and socio-economic aspects (e.g. tribal, low developed, etc.). When composing the legend, the order of the different features is hierarchical based on their importance.

Development of the livelihood zone profile

On the basis of the attribute table a narrative description of the livelihood zone profile is developed and forms the knowledge base of the country-level livelihood zoning. The profile includes the qualitative and quantitative information obtained from literature review, data collection and expert consultations. This information is information, to the extent possible, is re-aggregated and displayed by livelihood zone.

Assessing the role of AWM to improve rural livelihoods

Mapping potential beneficiaries and opportunities for AWM interventions

This step of the approach aims to assess the role of AWM to improve rural livelihoods at country level and, in particular, to assess the entry point for AWM to improve livelihoods and to identify the location where investments in AWM are most likely to have the maximum impact on rural livelihoods.

The participatory mapping process allows for the gathering of national experts' perspectives on how and where AWM can contribute to improving the lives of smallholders and facilitate definition and assessment of the different key factors determining where AWM interventions could be prioritized to support smallholders. Different factors emerged after findings were elaborated from the different participatory workshops; a few emerged strongly in all countries. These factors are seen as the basic conditions required for defining the areas where the maximum number of beneficiaries can be reached (in number and percentage). These factors follow the guiding principles:

- where rural population density is highest;
- where water is a key constraint for livelihoods; and
- where water is available (where it is sufficient for a range of AWM options).

On this basis, to ensure harmonization and comparison between the countries, the same factors have been adopted in each country to define the AWM potential beneficiaries and opportunities for AWM interventions.

These factors are expressed as follows:

- population factor (**P**^{r}), rural population in a given livelihood zone;
- demand factor (**D**), expressed as percentage of rural population perceiving water (management) as the main limiting factor for agricultural production;
- supply factor (**S**), expressed as percentage of rural population whose water demand would be fulfilled, given the current water availability (IRWR/person/year).
    - The assumption here is that, below a minimum threshold of 500 m^3/person only a limited share of the population will be able to benefit from AWM, and that the percentage of the population with access to water for agriculture increases as an exponential function of water resources, as shown in Figure 9.

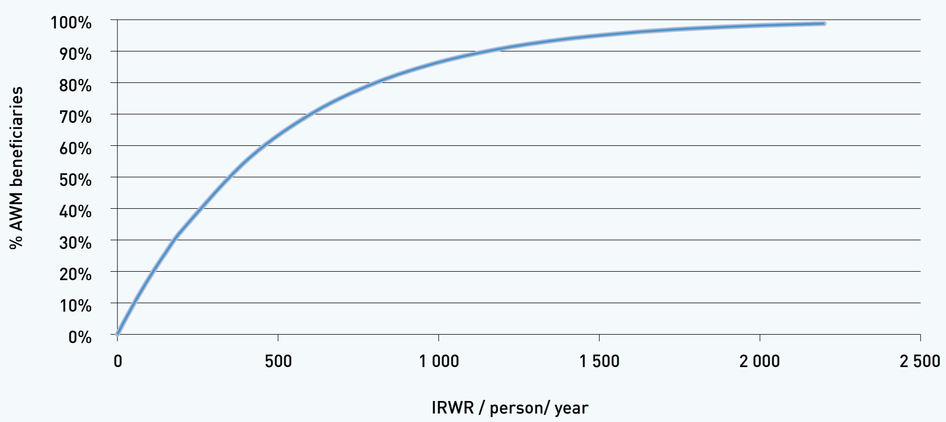
The number of potential beneficiaries is then obtained through the following formula that combines the three factors:

$$N_{ben} = P_r * (\text{Min } (D, S))$$

The number of potential beneficiaries is assessed on the basis of water demand, and constrained by the amount of IRWR per person:

The demand, or perception of water as the main limiting factor, is assessed during the participatory mapping process, gathering the national experts' and stakeholders' perspective on the importance of

Figure 9 Percentage of population whose water requirements could be fulfilled as a function of water resources



water and the role of AWM in the different livelihoods contexts. It is not expressed by data and statistics; it is qualitative and mainly assessed based on the description of the livelihood zones. However, different data and statistical information have been taken into consideration to back up and consolidate the stakeholders' perspective. This information is meant to better describe and explain the relationship between water, population and livelihoods and particularly how population is dependent on water and vulnerable to its uneven and insecure availability. Population pressure on land and water, erratic rainfall and seasonality, vulnerability to droughts and dry spells are examples of situations where the lack of secured access to sufficient water represents a major constraint for rural livelihoods.

The resulting, 'resources-constrained demand' is multiplied by the rural population in order to obtain an estimate of the potential beneficiaries in each livelihoods zone. This figure is then represented on a map, both as an absolute number (density of beneficiaries) and as a percentage of the total rural population, to highlight in-country variations and thus the need for context specific investments. In particular, the density map will indicate where AWM is likely to impact the largest number of beneficiaries, whereas the percentage map will better capture areas where AWM could benefit a higher share (and the need for AWM is more spread), although the absolute number of beneficiaries might be comparatively lower.

The main outputs are: i) national/state maps showing potential beneficiaries of agricultural water management interventions, expressed as density of people and as percentage of rural population, by livelihood zone (see example in Figure 10) and, ii) tables of distribution of beneficiaries and application area by livelihoods zones and/or administrative units (see example in Table 5).

Figure 10 Potential beneficiaries of AWM interventions in Ethiopia

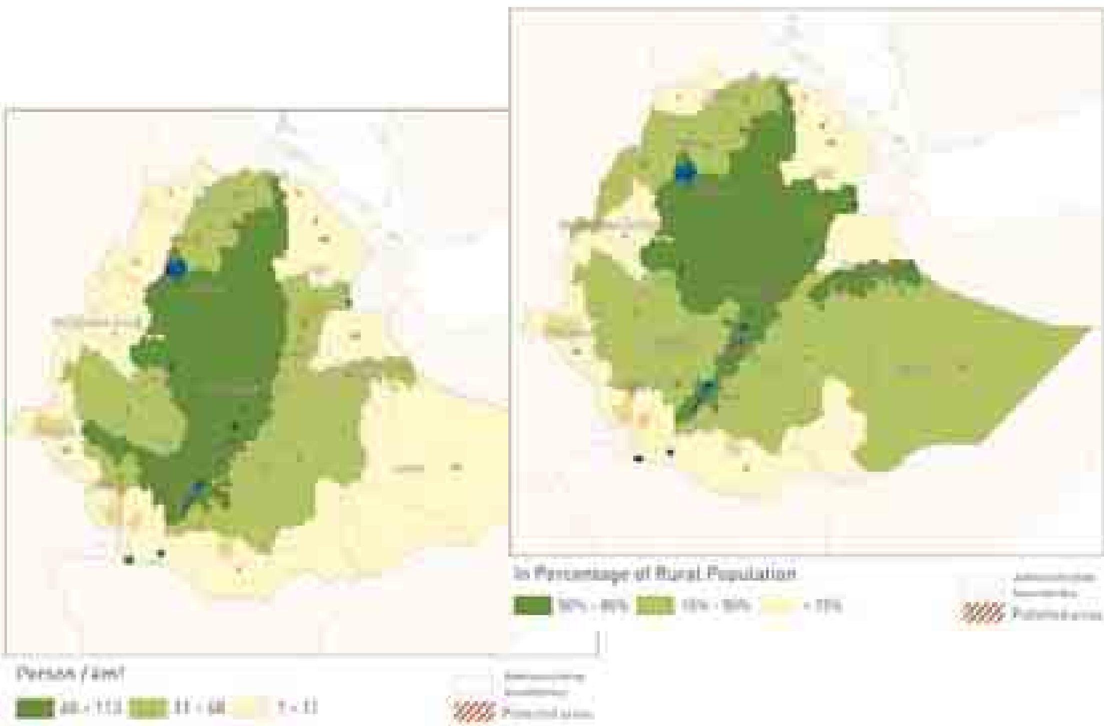


Table 5 Potential beneficiaries of AWM interventions in Ethiopia

Livelihood zone No.	Water availability: IRWR/cp (m³/p/y)	Rural population			Perception of water as limiting factor for agricultural production	Potential beneficiaries	
		Total (1 000s)	Density (p/km²)	Percentage of poor (underweight)		Person (1 000s)	In percentage of rural population
1	1 085	522	30	48.4	Low	78	15
2	406	2 397	112	48.0	Medium	1 199	50
3	1 286	2 194	100	51.5	Medium	1 097	50
4	16 379	729	19	43.4	Low	109	15
5	3 822	7 262	97	44.2	High	3 631	50
6	2 517	1 601	13	44.9	Low	240	15
7	1 379	7 371	56	43.5	Medium	3 686	50
8	787	889	25	50.4	High	705	79
9	492	4 318	117	50.6	High	2 705	63
10	843	814	10	50.3	Low	122	15
11	184	3 809	179	42.2	High	1 173	31%
12	1 178	2 612	12	43.2	Medium	1 306	50%
13	2 069	17 294	137	48.2	High	13 835	80%
14	994	9 166	187	51.1	Medium	4 583	50
15	468	5 391	186	46.0	High	3 278	61
16	6 645	470	10	43.8	Low	70	15
17	6 223	951	22	49.0	Medium	475	50

Development of an interactive computer tool for scenario analysis

The assessment of the relative importance of water management in the different livelihoods zones – expressed as number of potential beneficiaries of AWM interventions - bears a certain level of subjectivity and it is unlikely that all stakeholders can agree on a single final result.

As a matter of fact, when such results are presented, debates – or even arguments- raise among representatives of different local priorities, who may have the perception that needs and constraints in their area were underestimated in the assessment. In order to solicit constructive feedback it is important to give to stakeholders the opportunity to draw their own map, and compare it with others'- sometimes conflicting – opinions.

To this purpose an Excel-based tool has been developed which allows users to edit the parameters, and their relative weight, on which these results are build, in an intuitive and flexible way, while keeping the same methodological approach. A sketch of the livelihoods zones is imported in an Excel spreadsheet, and a color coding applied to the zones based on the assessment of the opportunities for AWM interventions to improve rural livelihoods: dark green areas are those were AWM is assumed to have higher impacts in terms of beneficiaries. Just like in the static maps, the number of beneficiaries is here given by the combination of the factors: i) where rural population density is highest; ii) where water is perceived as a key constraint for livelihoods; and iii) where water is available (where it is sufficient for a range of AWM options).

By changing these parameters, users can verify how the changes they propose affect the national or state level assessment and eventually reach a consensus (or at least awareness of the implications of their perception).

However, priorities for intervention can be based on different types of criteria, according, for instance on national or local level policy priorities. For this, the tool has been conceived as flexible instrument that can be easily customized by changing the parameters. Figures 11 and 12 show a screenshot of the Excel-based interactive tool on opportunities for AWM interventions in West Bengal, before and after users' defined parameters (circled) are set.

The underlying macro was adapted from Excelcharts.com:
http://www.excelcharts.com/blog/how-to-create-thematic-map-excel/

Figure 11 Screenshot of the Excel-based interactive tool in West Bengal, before users' defined parameters are set

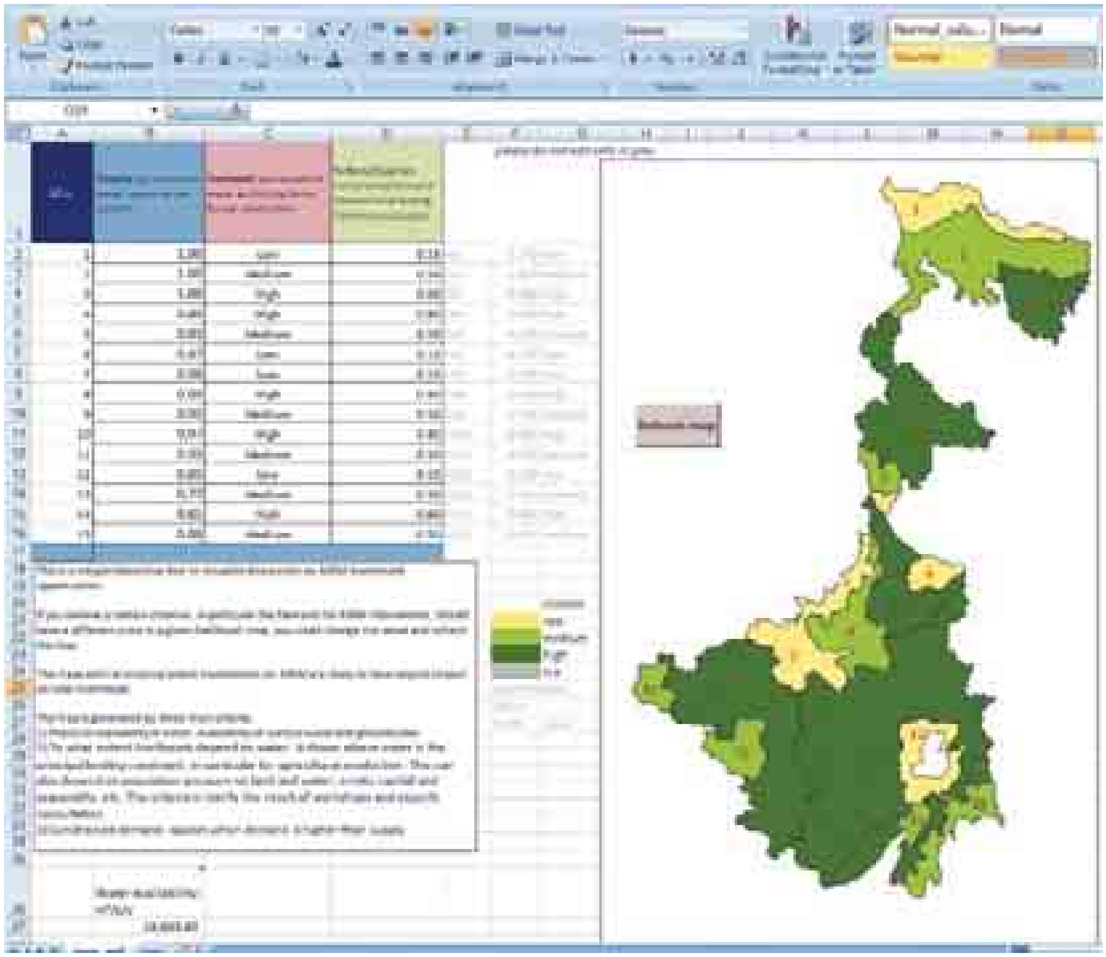
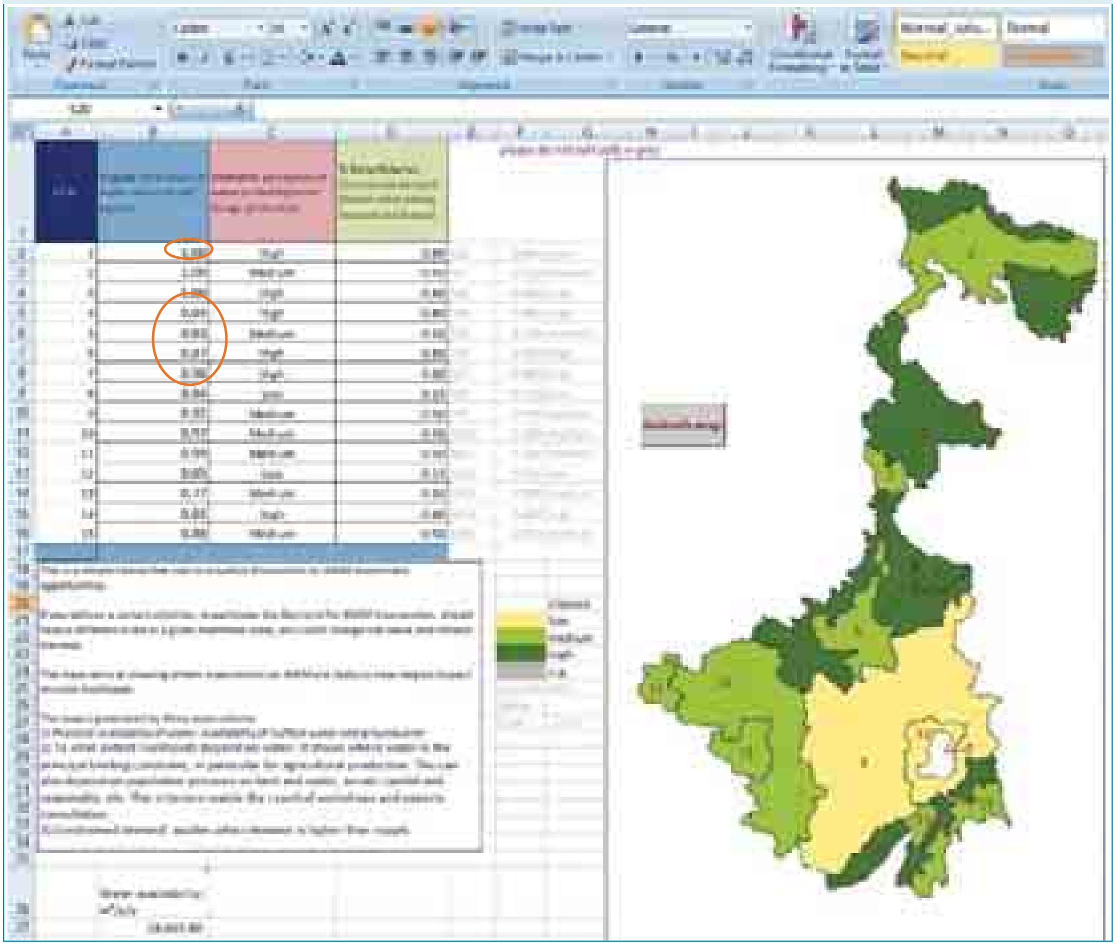


Figure 12 Screenshot of the Excel-based interactive tool in West Bengal, after users' defined parameters are set



Assessing suitability by type of AWM intervention

Mapping biophysical suitability by type of intervention

This process aims to define and map geographical domains of suitability for specific AWM technologies. These domains represent the area in a country where there are suitable biophysical conditions for the adoption of specific AWM solutions and to benefit smallholder livelihoods.

By considering the different country livelihood conditions obtained using the livelihood zone mapping, the domain represents the area where the given AWM technology is suitable for smallholder livelihoods. See Annex 3 for a list of analyses and descriptions of AWM solutions.

The map uses a set of criteria to assess the potential geographical extent of each AWM solution. These criteria represent the distribution of the biophysical conditions under which a AWM solution can have the potential highest impact on livelihoods.

As a first step, the process includes a review of available information on the biophysical and socio-economic conditions for successful adoption of each AWM intervention in the different country livelihood contexts to define different variables that have spatial correlation and the determinants used for the suitability of an AWM intervention.

The first step includes a review of available information of the conditions for successful adoption of each intervention as found in:

i) IWMI database on 'scaling-up potential' of existing AWM solutions ii) researchers' case study findings, collected in an ad hoc questionnaire (see Annex 4), and iii) local knowledge.

The second step is to identify the criteria to be used for the suitability mapping exercise, and define thresholds and spatial analysis expressions. These criteria must be designed based on the available data, a choice that, in some cases, may be constraining. The example in Table 6 refers to biophysical suitability criteria developed for motor pumps and for small reservoirs in Ethiopia.

Table 6 Biophysical suitability criteria for motor pumps and small reservoirs in Ethiopia

Parameters	Extent (A)	Surface water (B)	Shallow groundwater (C)	Market accessibility (D)	Livestock density (E)	AEZ (F)	Expression
Motor pumps	Cropland	< 1 km distance from surface water OR runoff > 300 mm/yr	Presence of fluvisols/ gleysols/gleyic subunits in soil profile	**High priority**: < 4 hr from markets. **Low priority**: > 4 hr			*If (A = B) OR (A = C) then apply D*
Small reservoirs	Cropland or non-forest natural vegetation				**High**: > 30 TLU equivalent ruminants, **Low**: < 30 TLU	0.2 < Aridity Index < 0.65	*If (A = F) then apply E*

TLU – Tropical Livestock Unit

The third step concerns validation of the results. Results of the second step are expressed in terms of area and compared to literature/experts' opinion: whenever major discrepancies are found, a sensitivity analysis is performed on the parameters used in the computation. In many instances lack of accuracy originates from inappropriate input data resolution: for example, surface water and, in particular, hydrological network which is very much scale-dependant (stream lines are delineated according to a minimum upstream area threshold). To overcome limitations because of resolution of the river network, modelled runoff has been used to include areas where there is potentially surface water, regardless of the network resolution.

Datasets and criteria are then processed using GIS to generate maps that show the suitability domain for the AWM intervention. The model distinguishes two levels of suitability:

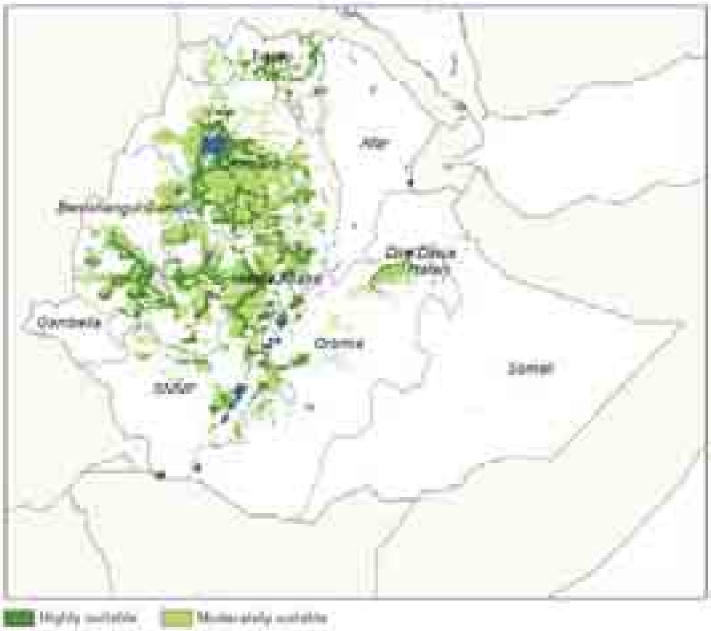
- High suitability – areas that present optimal conditions both in terms of biophysical and socio-economic conditions for adoption of a given AWM technology.
- Moderate suitability – areas where there are possibilities for application of a given AWM technology, but where conditions and impact on rural livelihoods are less favourable.

The main outputs are maps showing the two different levels of suitability per AWM solutions per country (see Figure 13).

Mapping livelihood-based demand

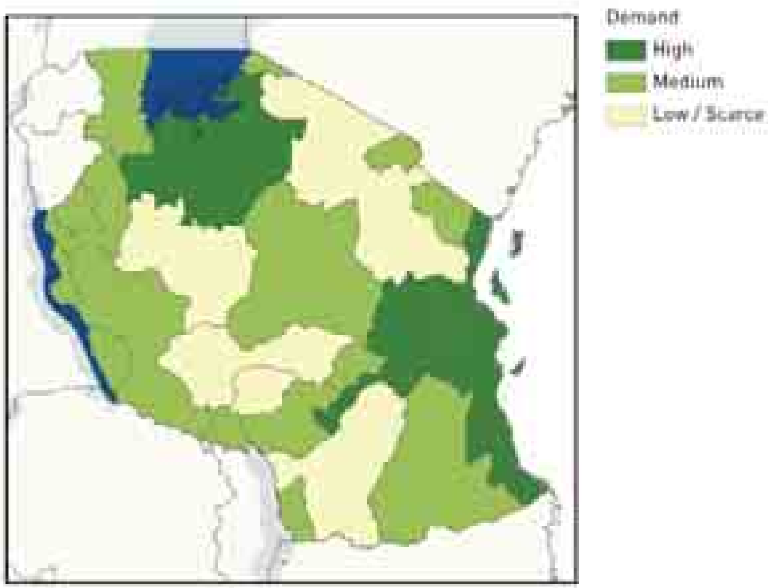
The participatory consultations and information analysis facilitates the identification and description of factors characterizing livelihood patterns, which are not easily represented by available data and have limited spatial correlation. These are analysed in the different country livelihood zones and allows for identification of the the areas where livelihood conditions are more favourable for a given technology.

Figure 13 Map of biophysical suitability for small motor pumps in Ethiopia



These factors reflect the importance of a technology for the population living in the livelihood zone and provide more in-depth information on the potential adopters. These livelihood-based demand factors are for instance: farmer typology and attitude, vulnerability to shocks, dependence on water resources, and average landholding size. A list of livelihood demand criteria per AWM solution in each country is available in Annex 6. The resulting map shows distribution of these factors in the different livelihood zones, which in turn identify areas where livelihoods' conditions are more favourable for a given AWM solution. An example of a livelihood-based demand is shown in Figure 14.

Figure 14 Livelihood-based demand for soil and water conservation measures in Tanzania



Assessing potential: areas and beneficiaries

The objective is to estimate and quantify the potential benefits of investing in AWM. The assessment is based on the mapping process of AWM solution domains. The maps developed for each AWM solution are used to quantify the number of potential beneficiaries and the area of land that could benefit from any of the solutions.

These calculations represent a 'gross' potential and do not take into account demand-side aspects of agricultural production. The calculations are performed according to the following steps:

- **Calculating the rural population residing in the AWM solutions suitability domains**: the total number of rural people falling into the areas of high or low suitability is calculated on the basis of a rural population density map. These results are then aggregated by livelihood zone.
- **Establishing a livelihood-based demand rate on the basis of the livelihood typology**: as described under *Mapping livelihood-based demand*, the livelihood-based demand factors allow assessment of the different livelihood zones or the rural population most likely to benefit from a given AMW solution. These factors reflect the importance of a given solution for the population living in the livelihood zone and provide in-depth information of the real potential adopters. On the basis of the livelihood-based demand factors, *a livelihood demand* rate, integrating the different factors (when available), is established and is applied as a multiplying factor.
- **Assessing the number of potential beneficiaries**: the *livelihood demand* rate is then applied as a multiplying factor to the number of rural people residing in the suitability domains to obtain the potential beneficiaries. See Box 2 for an example of the assessment of potential beneficiaries.

Box 2 Assessing the livelihood-based demand rate: example for motor pumps

In a certain livelihood zone, the livelihood demand rate (the percentage of farmers who may benefit from a given AWM solution) is determined by one factor, the farmer typology. For this solution, emerging market-oriented smallholder farmers are considered to be the main target beneficiaries, as this technology would imply higher production of high-value crops for market sales. Other categories of rural people are likely to be much less interested in such technology. It is the case, for instance, of pastoralists, who may probably not see any direct benefit from small motor pumps.

The assessment of demand is performed as follows: in the high suitability areas for motorized pumps, the portion of emerging smallholders (30 %) of rural population would represent the number of primary beneficiaries that reside in the highly suitable areas. Instead, the remaining percentage of traditional farmers (70 %), which are still compatible but less in demand for this AWM option, would be considered as secondary beneficiaries. In the moderately suitable areas, both the emerging and traditional smallholders would be taken into consideration and would represent secondary beneficiaries. These would be added to the portion of secondary beneficiaries of the highly suitable areas.

- **Assessing the number of households**: based on the national statistics, average household size is assigned to each country. The number of individual beneficiaries is then grouped by number of households. Table 7 shows the average household size in the project countries.
- **Establishing a household land application coefficient for each AWM solution**: to estimate the actual application area of a specific AWM option, a unit area of land per household that can benefit from a given AWM solution is established based

Table 7 Average household size by country

Country	Average household size
Burkina Faso	6.7
Ethiopia	5.2
Ghana	4
Tanzania	5.2
Zambia	4.8
India	4.5

on information obtained from the case studies and literature. However these values may be different from country-to-country. Table 8 shows the coefficients used for the AWM Solutions Project.

- **Assessing the extent of potential application area**: the number of potential beneficiaries, expressed as number of households, is then used to calculate the extent of land that could benefit from the solution. The result is assessed against the current extent of the cropland in the suitable area, and in terms of its impact on the water balance, and adjusted downwards if needed.
- **Summary tables by livelihood zone and administrative units**: the results obtained are displayed in tables or charts by livelihood zone and show the range of potential number of beneficiaries and application area. The range takes into account both the primary and the secondary potential beneficiaries or application area. An example for Madhya Pradesh is shown in Table 9 and 10.

Table 8 AWM solutions land application coefficients

AWM option	Ha/household
Motorized pumps	0.8*
Inland valley-bottom rice production	1.5
Small Reservoirs	1
Water harvesting ponds (ex situ)	1.5
Community level river diversion	1
Conservation agriculture (In-situ water harvesting, terracing)	Country average (cultivated land per household)

* In West Bengal the land application coefficient for low-cost pumps (both for the AWM solutions: rural electrification and diesel subsidies) is 0.4 ha/household

General assumption on adoption rate: Taking into account the uncertainty related to market capacity as well as the willingness and capacity of single farmers to adopt the specific AWM solution, it has been assumed that 50 percent of farmers, who could benefit from the AWM option, would be able to adopt it. Therefore the figures for potential beneficiaries and application area reflect the 50 percent-adoption assumption.

Table 9 estimates the number of rural people who can be reached in each livelihood zone by the AWM intervention – the assessment considers households rather than people (therefore, that which

Table 9 Example of potential beneficiaries of AWM solutions (Madhya Pradesh - India)

Livelihood zones	Water-harvesting ponds				Soil and water conservation (Field bunding)			
	(1 000 households)		(Percentage total households)		(1 000 ha)		(Percentage total agricultural land	
	min	max	min	max	min	max	min	max
1	17	146	1	6	130	153	5	6
2	2	15	0	1	69	74	5	5
3	10	165	0	4	183	216	5	6
4	118	300	2	5	217	324	4	6
5	13	54	0	2	55	79	2	3
6	21	44	2	4	27	50	3	5
7	12	19	0	1	40	92	1	3
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...

Table 10 Example of potential application area for AWM solutions (Madhya Pradesh - India)

Livelihood zones	Water-harvesting ponds				Soil and water conservation (Field bunding)			
	(1 000 ha)		(Percentage total agricultural land		(1 000 ha)		(Percentage total agricultural land	
	min	max	min	max	min	max	min	max
1	25	218	3	22	288	339	29	34
2	3	22	1	5	153	165	36	39
3	15	248	1	16	407	479	27	32
4	177	450	8	22	483	720	23	34
5	20	80	2	9	122	175	14	20
6	31	66	9	18	60	111	17	31
7	18	28	2	3	88	203	10	23
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...

benefits a smallholder farmer benefits the whole family). The interventions are not all mutually exclusive. Thus, it can be expected that a person may benefit from one or more of the proposed solutions.

Hydrological constraint

Hydrological aspects have been taken into consideration for calculation of potential beneficiaries and application area for the different AWM solutions. Specifically, impacts have been assessed for unrestricted potential adoption of water resources, expressed as a percentage of IRWR consumed by irrigation.

In general, it has been established that water resources consumed by the total number of beneficiaries should not be more than 30 percent of annual internal renewable water resources, which are represented by the annual runoff. Specifically, the potential area for application of AWM options should not exceed the extent that requires more than 30 percent of the annual runoff.

The water consumed annually by each AWM solution and technology has been estimated using the a general crop–water requirement based on expert consultations and available information from FAO studies in similar contexts. The annual crop–water is approximately 7 500 m^3/ha/yr. On this basis the hydrological constraint has been calculated as per the example in Table 11.

In Table 11, the total water resources needed to irrigate the area suitable for small motor pumps in livelihood zone 6 would exceed 30 percent of the annual available runoff. In this case, the suitable area for this AWM solution should be adjusted accordingly.

This method is simple and based on assumptions and allow for a rough estimation of macroscopic hydrological constraints, which are assessed at the appropriate scale and level, i.e. the basin or sub-basin. Therefore it should be used in context where physical water scarcity is not crucial. For this, in countries and contexts particularly constrained by water scarcity, the impact of unrestricted potential adoption on water resources, expressed as percentage of IRWR consumed by irrigation, it is recommended that assessment be more detailed following a specific procedure. Below an example of the procedure applied in Burkina Faso:

Table 11 Example of calculation of hydrological constraint by livelihood zone (Burkina Faso)

Hydrological constraint - small motor pumps (Burkina Faso)					
Livelihood zones	Suitable area (ha)	Available runoff (m3/ha)	Water resources needed * (Mm^3)	Runoff available in livelihood zone (Mm^3)	Percentage of runoff used (water needed/ available runoff)
1	11 846	326	89	1 021	9
2	13 532	450	101	1 499	7
3	25 074	1 272	188	1 942	10
4	10 836	3 041	81	358	23
5	21 272	3 695	160	808	20
6	12 991	337	97	200	49
...	...	...	...	...	...
...	...	...	...	...	...

* 7 500 m^3/ha

- Yearly evapotranspiration resulting from irrigation is estimated over potential areas of adoption. This is done by assessing the freshwater resources and evapotranspiration needs using a soil–water balance model, which is then compared with irrigation water requirements for the given crops (rice for *bas-fonds* and vegetables for small reservoirs and pumps in this case)[3].
  - The results are aggregated at basin level to show the cumulative impact of increased consumptive use of water for irrigation on each basin freshwater resources.

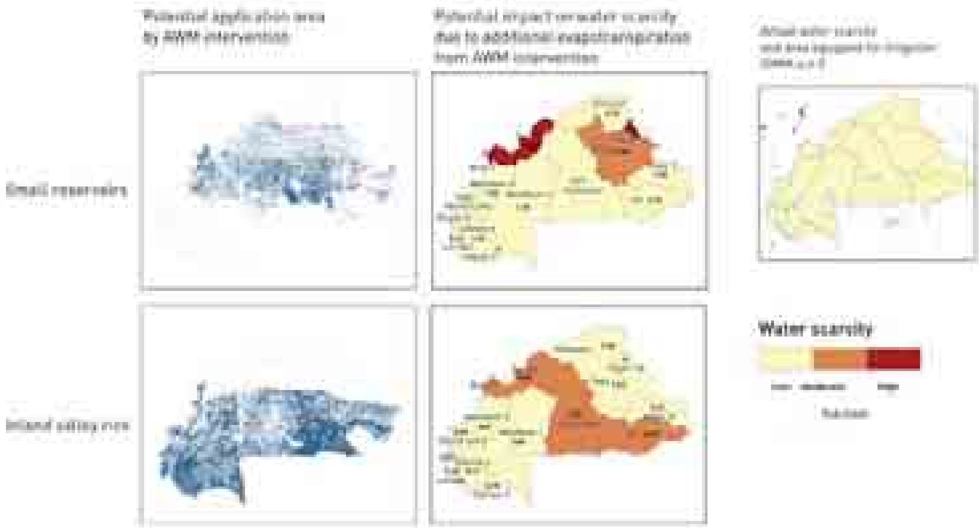
As a rule of thumb, in Burkina Faso a basin can be classified as moderately water scarce when irrigation water consumption (IWC) /IRWR > 6 percent, and highly water scarce when IWC/IRWR > 12 percent. This threshold takes into account water lost in the distribution: water requirement ratio (ratio between estimated crop water requirement and actual withdrawal) in Burkina Faso is estimated at 30 percent [4], therefore a value of 12 percent denotes that 40 percent of IRWR is withdrawn for irrigation use only (i.e. not including domestic, industrial, environmental and other agricultural uses).

This preliminary analysis has a number of limitations related to the – unaccounted – overlap of interventions, but it provides a draft methodology on how to assess the impact of interventions on water resources, keeping in mind that this has been tested on the unrestricted potential only, whereas economic demand constraints would most probably limit such an impact to a negligible extent.

[3] The approach is described in more detail in World agriculture: towards 2015/2030, http://www.fao.org/DOCREP/005/Y4252E/Y4252E00.HTM and *The State of Land and Water Resources for Food and Agriculture: Managing Systems at Risk* (FAO, 2011)

[4] AQUASTAT: http://www.fao.org/nr/water/aquastat/water_use_agr/irrwatuse.htm

Figure 15 Burkina Faso Impact of water scarcity; irrigation water consumption as percentage of IRWR



Sub-basin name	Small reservoir	Bas-fonds	Actual (GMIA 4)
Sourou	12.1%	8.9%	5.8%
Mouhoun 2	1.9%	5.0%	0.8%
Mouhoun 1	1.2%	5.8%	0.2%
Nakambe	3.7%	7.2%	0.5%
Oti	1.8%	6.7%	0.1%
Leraba	0.2%	2.1%	0.2%
Comoe 6	1.4%	4.7%	1.4%
Comoe 5	0.0%	2.8%	0.0%
Bagoe 2	0.0%	2.4%	0.0%
Ngora Laka	0.2%	2.5%	0.2%
Bani 1	2.2%	0.0%	0.0%
Gorouol	4.3%	0.9%	0.9%
Niger 10	14.8%	0.0%	0.0%
Faga	6.3%	5.6%	0.1%
Niger 9	1.5%	5.4%	0.1%

Assessing the investment costs

This section presents the results of an exercise to estimate the possible costs of a programme of investments in water in support of rural livelihoods. It is based on an assessment of the potential application of each of the AWM intervention options analysed in the different countries (Annex 3).

Unit costs by type of intervention were estimated based on expert consultations and on available information from investment projects used by FAO for similar regional assessments. In view of the wide-range of possible interventions and associated costs, such an assessment can only be viewed as a very rough estimate of such a potential for action and associated costs. Substantial differences can be expected from one livelihood zone to another, and from one place to another within a given zone.

The tentative investment costs are presented for each type of AWM solution or technology by livelihood zone in each country. To calculate the costs by livelihood zone, the unit costs are multiplied by the number of beneficiaries, or areas of application, depending on the nature of the unit cost (either expressed per person/household or per hectare). The investment costs would then be expressed by a range of values (minimum and maximum). This is because of the range of the potential beneficiaries and application area (priority and secondary beneficiaries.

Annex 7 presents the different unit costs and assumptions adopted per AWM solution in each country.

Validation process

This is a crucial phase of the approach, the closure of the overall process, which integrates participatory processes with data processing and elaboration phases. This phase is meant to revise and validate all the outputs developed through the approach. More precisely, the phase aims to revise and validate the following outputs:

- livelihood zones map and description;
- national map of potential beneficiaries from AWM interventions; and
- suitability domains map of specific AWM solutions.

The validation phase entails national and subnational level stakeholder consultations. The national level consultation aims to revise the entire mapping process and outputs. The main objective of the subnational consultation is to obtain a more in-depth insight into regional/local level AWM issues, is also an opportunity to analyse AWM aspects in more detail and to ensure compliance with national level mapping. These consultations are important in ensuring ownership of the process and outputs by the major country actors who have contributed to the outputs throughout their development.

The validation phase involves the use of available field level data and information that allow ensuring the validity and rectify, if needed, the outputs obtained. When possible, specific field surveys have been conducted for ground-truthing purposes.

Participatory national validation workshop

The purpose of this workshop is to involve country and local level experts and stakeholders in the AWM and other related fields to revise and validate the preliminary outputs of the analysis. Most participants have participated and contributed to the participatory mapping process; although the emphasis on this workshop is more on the AWM aspects. The workshop is made up of three different sections in plenary and working groups to revise and validate the three typologies of maps: i) livelihood zones (including the attribute table and legend); ii) the AWM investment potential and iii) the AWM solution suitability domains.

Livelihood zones map

The livelihood zones map is the primary output of the previous mapping workshop and has, therefore, gone through in-depth participatory work. Moreover, the map has been accurately consolidated making use of available datasets, statistics and other secondary data and information. The revision process of this map is conducted in a plenary phase to obtain general feedback and fine-tune the zone description and labelling.

National map of potential beneficiaries from AWM interventions

This section is conducted in both working groups and plenary processes. The working groups to use the Excel-based tool, which allows participants to build a map using the three criteria (see Section Development of an interactive computer tool for scenario analysis). The tool enables the participants to assess the importance of each criterion, by assigning an overall weight, and their relevance to the different livelihood zones by assigning a score (0.25, 0.5, 0.75 and 1). The tool computes the different values and generates a map that can be displayed for discussions. The working groups report back in plenary for discussion and to obtain a final synthesis map.

AWM solution suitability domain map

This section is conducted in both working groups and plenary processes. The purpose of this session is to revise the parameters and conditions that determine the suitability of a given AWM technology or solutions and the highest impact on smallholder farmers' livelihoods. The revised criteria are used to refine the suitability domain maps for the different AWM solutions analysed in the project. The working groups are to fill in a set of forms that identify the key criteria determining the suitability of a given solution, their relevance (from low to high) and the conditions that determine their suitability. Here below an example of the form for river diversion and low-cost motor pumps in Zambia.

Table 12 Example of validation workshop form: Suitability domains for river diversion schemes (Zambia)

Criteria	Relevance (H/M/L)	Possible conditions required for successful scaling up
Climate/moisture regime		Suitable in dry sub-humid and humid areas
Credit	Low	It might help to improve the structures
Crop type	High	Suitable for vegetable crops, maize, row crops
Electrification		
Extension services	High	In terms of water management and irrigation scheduling
Farmer typology	Medium	More suitable for emergent farmers
Land rights	High	Need land rights for farrow access
Surface water	High	Within a 5 km radius from perennial rivers

Another important purpose of this section is to relate the AWM solutions to the livelihood context and more precisely to fill in a form to revise the relevance of various solutions in the various livelihood zones and the different farmers typologies. Here below is an example:

Table 13 Example of validation workshop form: Suitability domains for low-cost motor pumps (Zambia)

LZ zones	For whom – typical farmers	why these farmers? For what purpose?	What are the main adoption constraints in this area?
1	Market oriented	High-value crops	Market access (bad road / infrastructure)
2	Market oriented	Rice production	Market access
7	Traditional	Rice production and livestock	Land shortage, animal damage to crops
10	Traditional	Livestock watering	Credit, investment costs
16	...	...	...

The groups then report back in plenary for discussion and synthesis.

Subnational workshops

Another important part of the consultation for local validation of the results is the subnational AWM workshop. These events are generally organized in the regions/provinces where AWM has been identified as potentially important for improving livelihoods. The key workshop participants are local experts and stakeholders involved in the AWM sector and, in particular, local institutions, NGOs and farmers groups and associations.

The workshop allows for an in-depth review of the local situation in relation to water and to obtain a more precise estimate of the constraints, opportunities and challenges as well as the AWM intervention priority for specific solutions. The workshop provides an opportunity to obtain feedback and gain deeper insight into the mapping work from the perspective of local stakeholders at the local level.

Conclusions

1. Livelihood mapping: a basis to target beneficiaries

In general terms, a livelihoods approach can be distinguished from a production-based approach in that it makes the household as the centre of analysis, taking an integrated view of the importance of all a household's assets or forms of capital (physical, financial, human, natural and social) (FAO and IFAD, 2008). This perspective provides the basis to move from a yield-increase objective to a more secure, stabilized and diversified production one, switching the focus to people's needs. Any rural water development strategy will have to deal with multi-local diversified livelihood systems with limited capacities for agricultural investment, a predominance of risk-avoiding strategies (IFAD, 2005). In terms of water, this means, "a fundamental shift beyond considering water as a resource for food production to focusing on people and the role water plays in their livelihood strategies" (WWAP, 2006).

Mapping livelihoods allows practitioners to focus on the key beneficiaries, on their constraints and priorities. The approach is context-specific and helps target the different smallholders based on their livelihoods and priorities. Thus, there is no "one size fits all" approach, no "blanket solutions" for improving livelihoods. The analysis conducted in the different countries also shows that different contexts have different needs and require different types of investments. The overall livelihood context (including the institutional environment) can guide the choice of investment from a non-prescriptive menu of appropriate interventions at different scales. In this context, any AWM investment strategy should not be technology-driven, but should be in compliance with the livelihood context and take into account the capacity of smallholders to adopt a given technology.

2. A tool for rapid appraisal to support decision-making about AWM interventions

The approach illustrated in this report is a tool to conduct country-level rapid appraisals to identify and target AWM solutions in support of rural livelihoods. This can also be seen as a powerful instrument to support the decision process. The application of the methodology allows decision-makers to prioritize areas for interventions and give them tools they can use to understand the potential for scaling-up different AWM interventions. Decision-makers are often requested to take investment decisions without any overall view of the country context and often with inconsistent information that hampers decision-making. They often seek recommendations and guidance in understanding key elements for taking investment decisions: i) Where to invest? ii) Who to benefit? iii) What approach to adopt? This approach can be a rapid and pragmatic route to provide basic recommendations and answer these questions. More specifically, it provides guidance regarding who the beneficiaries are and how many, where they are, what their needs are, and how AWM can improve livelihoods and with which intervention options.

In summary, the approach can guide the decision process on where to invest to benefit the largest number of people and to have the highest impact on their livelihoods, and it gives recommendations in a simple, transparent and straightforward manner, making use of visual information (maps and charts) and providing figures on potential beneficiaries and tentative investment costs.

The validation and vetting process through the involvement of the major country actors from different fields and institutions, ranging from farmers to policy makers, contributes identifying priorities in the different country livelihood contexts and consequently key promising AWM options to meet these needs. Moreover, this helps ensuring ownership of the process from the stakeholders who contributed to the outputs throughout the process. Hence, the results coming from the application of the methodology are useful in a national decision-context within a national policy dialogue and planning process and can be used to facilitate and support discussion, planning and the decision-making in general in a transparent and objective way.

3. Key challenges and issues to be addressed

The analysis conducted in the different countries has made use of national datasets, statistics and other information, needed to map and describe the livelihood context and the AWM potential. However, the analysis is limited by a lack of some key information or information that may be outdated. In many countries, data needed may be available but are often inaccessible or scattered. In some cases, data needed to express livelihoods determinants and AWM intervention suitability variables could not be included in the analysis. A further limitation was the limited spatial correlation of different livelihood determinants and AWM interventions suitability variables. Some of the determinants and variables identified cannot be easily expressed by spatially disaggregated datasets, particularly the socio-economic variables (e.g. farmer typologies, access to credit facilities, education, etc.). Finally, for some information there is a scale issue: some statistics and other data have limited disaggregation or are incomplete and scattered, or inaccurate at low administrative levels (e.g. districts, provinces). Therefore, these data do not have adequate national coverage and do not sufficiently represent the overall country context. To overcome these constraints, some national level datasets were replaced with global datasets (e.g. landcover, agroecological zones) in the analysis and have been harmonized across the different countries. Similarly, data gaps at low administrative levels have been re-aggregated or replaced with data collected at higher levels. In other cases, the analysis has benefited from the use of proxy data (e.g. potential shallow groundwater) to express different determinants and variables.

Overall, the key data-related constraints were addressed by using expert knowledge in a structured and systematic way through participatory consultations and individual feedback. This is an essential part of the process in capturing and synthesizing the most significant indicators in each national context. However, the use of expert knowledge in the analysis has been challenging due to the difficulty to integrate qualitative with quantitative data in a standardized way to further reduce subjectivity. For this, there is scope for improving data collection and processing.

4. Further developments

The methodology will be further developed to include a more detailed analysis of the economic and market aspects. In particular, it will be integrated with a specific economic component that will address accost-benefit aspects of the different investment options.

Glossary

Agricultural water management (AWM) – planned development, distribution and use of water resources in accordance with predetermined agriculture-related objectives. This includes technologies, products and practices to lift, store and distribute water for smallholder farmers.

Agro-ecological zones – are defined by FAO on the basis of the average annual length or growing period for crops, which depends mainly on precipitation and temperature. They are: humid (> 270 days); moist subhumid (180–269 days); dry subhumid (120–179 days); semi-arid (60–119 days); and arid (0–59 days).

AWM solution suitability domain – a suitability domain of a given AWM solution represents the area in a country where there are suitable biophysical and socio-economicconditions to benefit smallholders livelihoods. By considering the different country livelihood conditions obtained by the livelihood zone mapping, the domain represents the area where the given AWM solution is a priority for smallholders' livelihoods and determine its potential adoption.

AWM solutions or interventions – any measure that boosts the uptake of AWM and that: i) contributes to smallholder livelihoods; ii) benefits women and men and does not increase income disparities; iii) is cost-effective to implement; iv) can be scaled-up; v) addresses resource sustainability. These can include a combination of infrastructure investments (hard), policy reforms, institutional and financial support, capacity building, extension services, etc. (soft).

Commercial farmers – produce agricultural products intended for the market to be delivered, sold or stored in commercial structures and/or sold to end consumers (feedlots, poultry farms, dairies, etc.), fellow farmers and direct exports. They generally use high levels of inputs.

Cropping system – the cropping patterns used on a farm and their interaction with farm resources, other farm enterprises, and available technologies that determine their cultivation. The cropping system is a subsystem of a farming system.

Dry spell – short period of water stress during critical crop growth stages and which can occur with high frequency but with minor impacts compared with droughts.

Emerging smallholders – smallholder farmers with a higher level of technical knowledge and better receptivity to improved technology than traditional smallholders. They tend to specialize in specific crops, relying on irrigation and other types of water control, and tend to market their production surplus.

Farming system – a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of analysis, a farming system can encompass a few dozen or many millions of households.

Household – all the persons, kin and non-kin, who live in the same dwelling and share income, expenses and daily subsistence tasks.

Infrastructure – facilities, structures, and associated equipment and services that facilitate the flows of goods and services between individuals, enterprises and governments. It includes: public utilities (electric power, telecommunications, water supply, sanitation and sewerage, and waste disposal); public works (irrigation systems, schools, housing and hospitals); transport services (roads, railways, ports, waterways and airports); and research and development facilities.

In-situ water harvesting (Soil moisture management) – process of preventing runoff and inducing water infiltration in the soil, and then minimizing evaporation to the extent feasible in the cropping area.

Investment – outlays made by individuals, enterprises and governments to add to their capital. From the viewpoint of individual economic agents, buying property rights for existing capital is also an investment. However, from the viewpoint of an economy as a whole, only the creation of new capital is counted as an investment.

Irrigation potential – total possible area to be brought under irrigation in a given river basin, region or country, based on available water and land resources.

Irrigation – refers to water artificially applied to soil, and confined in time and space for the purpose of crop production. They are different type of irrigation systems depending of the level of control, institutional setting, farm size, etc. The equipment may be for permanent or supplementary irrigation.

Land tenure – the relationship, whether legally or customarily defined, between people, as individuals or groups, with respect to land and associated natural resources (water, trees, minerals, wildlife, etc.).

Livelihood zone – is a geographical area within which people broadly share the same livelihood patterns, including access to food, income, and markets.

Livelihood – comprises people, their capabilities and their means of living, including food, income and assets. Tangible assets are resources and stores, and intangible assets are claims and access. A livelihood is environmentally sustainable where it maintains or enhances the local and global assets on which livelihoods depend, and has net beneficial effects on other livelihoods. A livelihood is socially sustainable where it can cope with and recover from stresses and shocks, and provide for future generations.

Malnutrition – failure to achieve nutrient requirements, which can impair physical and/or mental health. It may result from consuming too little food, or a shortage of or imbalance in key nutrients (e.g. micronutrient deficiencies, or excess consumption of refined sugar and fat).

Multiple use of water – where water is used both for domestic, agricultural or other purposes, reflecting the realities of rural people's multifaceted water use.

Peri-urban agriculture – is an agricultural system developed around cities to take advantage of local markets for high-value crops (fruit, vegetables, dairy products, etc.).

Rainfed agriculture – agricultural practice relying exclusively on rainfall as its source of water.

Renewable water resources – average annual flow of rivers and recharge of groundwater generated from precipitation. Internal renewable water resources refer to the average annual flow of rivers and recharge of groundwater generated from endogenous precipitation.

Resilience – is the ability of a system (people or ecosystem) to recover quickly from a shock.

Rural population – rural people usually live in a farmstead or in groups of houses containing 5 000–10 000 persons, separated by farmland, pasture, trees or scrubland. Most rural people spend the majority of their working time on farms.

Smallholder farmers – this definition differs between countries and between agro-ecological zones. In favourable areas of sub-Saharan Africa with high population densities, they often cultivate less than 1 ha of land, whereas they may cultivate 10 ha or more in semi-arid areas, or manage ten head of livestock. Often, no sharp distinction between smallholders and other larger farms is necessary. Within the smallholder category, this study distinguishes two typologies: traditional and emerging.

Subsistence farming – a form of agriculture where almost all production is consumed by the household, often characterized by low-input use, generally provided by the farm.

Traditional smallholders – smallholder farmers based on traditional subsistence agriculture. Farming is generally rainfed, and production is mainly based on staple crops with low yields. Their main target is self-consumption.

Vulnerability – the characteristics of a person, group or an ecosystem that influence their capacity to anticipate, cope with, resist and recover from the impact of a hazard.

Water access – the degree to which a household can obtain the water it needs from any source in a reliable way for agriculture or other purposes.

Water control – the physical control of water from a source to the location at which the water is applied.

Water harvesting – the process of collecting and concentrating rainfall as runoff from a catchment area to be used in a smaller area, either for agriculture or other purposes.

Water scarcity – the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully.

Water withdrawal – the gross volume of water extracted from any source, either permanently or temporarily, for a given use. Agricultural water withdrawal refers to the annual volume of freshwater withdrawn for agricultural purposes.

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Annexes

Annex 1 – Mapping criteria for livelihood zones

Criteria		Expected data typology				Use		
Basic	**Derived**	**Spatial (national coverage)**	**Spatial (not national coverage)**	**Aggregated statistics (subnational level)**	**Defined by expert consultation**	**Livelihood zones boundary delineation**	**Livelihood zones description**	**Relevance with livelihood capitals**
Natural Resources and Geography								
Climate								
Rainfall		X				X		Natural
Temperature		X				X		Natural
ET		X				X		Natural
	Agro-ecological Zones	X				X		Natural
	Inter-annual rainfall variability	X					X	Natural
Topography								
Altitude		X				X		Natural
	Slope	X						Natural
Soil								
Soil type								Natural
	Soil characteristics (suitability for irr.)	X						Natural
Hydrology								
Waterbodies		X					X	Natural
Groundwater availability		X						Natural
	Distance to water sources	X						Physical
Water quality				X	X		X	Natural
	Incidence of dry-spells and droughts	X					X	Natural
Landcover								
Landcover patterns		X				X	X	Natural
Protected areas		X				X	X	Natural
Production patterns and land use								
Agriculture								
	Cropping systems	X			X	X	X	Natural

(Continued)

Criteria		Expected data typology				Use		
Basic	Derived	Spatial (national coverage)	Spatial (not national coverage)	Aggregated statistics (subnational level)	Defined by expert consultation	Livelihood zones boundary delineation	Livelihood zones description	Relevance with livelihood capitals
Distribution of cultivated crops		X				X	X	Natural
Livestock keeping								
Distribution of livestock		X				X	X	Financial
	Ratio population/ livestock	X				X	X	Financial/social
Other								
Mines			X		X	X	X	Financial/natural
	Other land uses	X				X	X	Financial/natural
Market and infrastructure								
Roads, railroads		X					X	Physical
	Distance to markets	X			X	X	X	Physical
Irrigation infrastructure		X					X	Physical
Dams, reservoirs		X					X	Physical
Socioeconomic patterns								
Rural population distribution		X			X		X	Social
Rural poverty, malnutrition distribution		X			X		X	Social
Farmers category				X	X		X	Social
Gender (Female, male headed households, etc.)			X		X		X	Social
Average household size				X	X		X	Social
Average landholding size				X	X		X	Financial
Level of education				X	X		X	Human
	Access to schools	X		X			X	Physical
Age classes				X	X		X	Human
Health (HIV rates)				X	X		X	Human
Income distribution			X	X	X		X	Financial
	Access to credit			X	X		X	Financial

Annex 2 – Data used

Name	Source/provider	Year (publication)	Country applied	Purpose	Link to download
Rural population density	FAO (adapted from ORNL Landscan)	2005	All	AWM Potential beneficiaries map	
Prevalence of underweight children	CIESIN SEDAC	2005	All	AWM Potential beneficiaries map	
Global map of yearly runoff	FAO		All	AWM Potential beneficiaries map	
Length of growing period	GAEZ v.3, FAO/IIASA	2011	Burkina Faso	Biophysical suitability: Inland valley-bottom rice	http://www.fao.org/nr/gaez/data-portal/en/
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	Burkina Faso	Biophysical suitability: Low-cost motor pumps	
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	Burkina Faso	Biophysical suitability: Inland valley-bottom rice	
Agricultural area	ADYSA (Atlas Dynamique sur la Sécurité Alimentaire), FAO/EC	2008	Burkina Faso	Biophysical suitability: Low-cost motor pumps	
Agricultural area	ADYSA (Atlas Dynamique sur la Sécurité Alimentaire), FAO/EC	2008	Burkina Faso	Biophysical suitability: Small dams	
Fluvisols/gleysols (inc. gleyic subunits)	Harmonized World Soil Database v1.1, FAO/IIASA/ISRIC/ISSCAS/JRC	2009	Burkina Faso	Biophysical suitability: Low-cost motor pumps	
Global map of yearly runoff	FAO	2010	Burkina Faso	Biophysical suitability: Low-cost motor pumps	
Distance to surface water	FAO, based on Hydrosheds and GLWD		Burkina Faso	Biophysical suitability: Low-cost motor pumps	
Gridded Livestock of the World	GLW, FAO	2011	Burkina Faso	Biophysical suitability: Small dams	http://www.fao.org:80/geonetwork?uuid=c6f03530-f317-11db-9a22-000d939bc5d8
Global Map of Aridity	FAO	2009	Burkina Faso	Biophysical suitability: Small dams	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Livelihood zone map	FEWS-NET, USAID		Burkina Faso	Livelihood zones: delineation, description and livelihood-based demand	
Fluvisols/gleysols (inc. gleyic subunits)	Harmonized World Soil Database v1.1, FAO/IIASA/ISRIC/ISSCAS/JRC	2009	Ethiopia	Biophysical suitability: Low-cost motor pumps	

(Continued)

Name	Source/provider	Year (publication)	Country applied	Purpose	Link to download
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	Ethiopia	Biophysical suitability: Low-cost motor pumps	
Global map of yearly runoff	FAO	2010	Ethiopia	Biophysical suitability: Low-cost motor pumps	
Distance to surface water	FAO, based on Hydrosheds and GLWD		Ethiopia	Biophysical suitability: Low-cost motor pumps	
Agricultural area	Globcover	2009	Ethiopia	Biophysical suitability: Low-cost motor pumps	http://www.fao.org:80/geonetwork?uuid=acdb1530-1840-4a91-a25e-09ee6e4d06e8
Gridded Livestock of the World	GLW, FAO	2011	Ethiopia	Biophysical suitability: Small dams	http://www.fao.org:80/geonetwork?uuid=c6f03530-f317-11db-9a22-000d939bc5d8
Global Map of Aridity	FAO	2009	Ethiopia	Biophysical suitability: Small dams	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Atlas of the Ethiopian Rural Economy	CSA, EDRI, IFPRI	2006	Ethiopia	Livelihood zones: delineation, description and livelihood-based demand	
Crop Production System Zones	FAO/IGADD	1998	Ethiopia	Livelihood zones: delineation, description and livelihood-based demand	
Land use	Ethiopian MoARD, FAO	2001	Ethiopia	Livelihood zones: delineation, description and livelihood-based demand	
Elevation	GAEZ v.3, FAO/IIASA, based on SRTM	2009	Ethiopia	Livelihood zones: delineation, description and livelihood-based demand	http://www.fao.org/nr/gaez/data-portal/en/
Rainfall (yearly, average 1961-1990)	FAO, based on CRU dataset	2000	Ethiopia	Livelihood zones: delineation, description and livelihood-based demand	http://www.fao.org:80/geonetwork?uuid=dabc5510-88fd-11da-a88f-000d939bc5d8
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	Ghana	Biophysical suitability: Inland valley-bottom rice	
Distance to rivers	FAO, based on Volta Basin starter kit, IWMI		Ghana	Biophysical suitability: Inland valley-bottom rice	
Slope	GAEZ v.3, FAO/IIASA, based on SRTM	2009	Ghana	Biophysical suitability: Inland valley-bottom rice	http://www.fao.org/nr/gaez/data-portal/en/

(Continued)

Name	Source/provider	Year (publication)	Country applied	Purpose	Link to download
Suitability for rice	GAEZ v.3, FAO/IIASA	2011	Ghana	Biophysical suitability: Inland valley-bottom rice	http://www.fao.org/nr/gaez/data-portal/en/
Fluvisols/gleysols (inc. gleyic subunits)	Harmonized World Soil Database v1.1, FAO/IIASA/ISRIC/ISSCAS/JRC	2009	Ghana	Biophysical suitability: Low-cost motor pumps	
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	Ghana	Biophysical suitability: Low-cost motor pumps	
Global map of yearly runoff	FAO	2010	Ghana	Biophysical suitability: Low-cost motor pumps	
Distance to surface water	FAO, based on Hydrosheds and GLWD		Ghana	Biophysical suitability: Low-cost motor pumps	
Gridded Livestock of the World	GLW, FAO	2011	Ghana	Biophysical suitability: Small dams	http://www.fao.org:80/geonetwork?uuid=c6f03530-f317-11db-9a22-000d939bc5d8
Global Map of Aridity	FAO	2009	Ghana	Biophysical suitability: Small dams	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Cropping patterns (extent of cropped area)	FAO, based on SRID, Ghana Min. of Food & Agriculture	2004	Ghana	Livelihood zones: delineation, description and livelihood-based demand	
Slope	GAEZ v.3, FAO/IIASA, based on SRTM	2009	Madhya Pradesh	Biophysical suitability: soil and water conservation - field bunding	http://www.fao.org/nr/gaez/data-portal/en/
Soil properties (vertisols)	Harmonized World Soil Database v1.1, FAO/IIASA/ISRIC/ISSCAS/JRC	2009	Madhya Pradesh	Biophysical suitability: soil and water conservation - in-situ water harvesting	
Slope	GAEZ v.3, FAO/IIASA, based on SRTM	2009	Madhya Pradesh	Biophysical suitability: soil and water conservation - in-situ water harvesting	http://www.fao.org/nr/gaez/data-portal/en/
Agroecological zones	Madhya Pradesh govt		Madhya Pradesh	Livelihood zones: delineation, description and livelihood-based demand	
Socio-cultural zones	Madhya Pradesh govt		Madhya Pradesh	Livelihood zones: delineation, description and livelihood-based demand	
Fluvisols/gleysols (inc. gleyic subunits)	Harmonized World Soil Database v1.1, FAO/IIASA/ISRIC/ISSCAS/JRC	2009	United Republic of Tanzania	Biophysical suitability: Low-cost motor pumps	

(Continued)

Name	Source/provider	Year (publication)	Country applied	Purpose	Link to download
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	United Republic of Tanzania	Biophysical suitability: Low-cost motor pumps	
Global map of yearly runoff	FAO	2010	United Republic of Tanzania	Biophysical suitability: Low-cost motor pumps	
Distance to surface water	FAO, based on Hydrosheds and GLWD		United Republic of Tanzania	Biophysical suitability: Low-cost motor pumps	
Agricultural area	FAO Africover	2003	United Republic of Tanzania	Biophysical suitability: Low-cost motor pumps	
Global Map of Aridity	FAO	2009	United Republic of Tanzania	Biophysical suitability: Community river diversion schemes	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Distance to rivers	FAO, based on Hydrosheds		United Republic of Tanzania	Biophysical suitability: Community river diversion schemes	
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	United Republic of Tanzania	Biophysical suitability: Community river diversion schemes	
Global Map of Aridity	FAO	2009	United Republic of Tanzania	Biophysical suitability: Soil and water conservation	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Slope	GAEZ v.3, FAO/IIASA, based on SRTM	2009	United Republic of Tanzania	Biophysical suitability: Soil and water conservation	http://www.fao.org/nr/gaez/data-portal/en/
Rainfall (yearly, average 1961-1990)	FAO, based on CRU dataset	2000	United Republic of Tanzania	Livelihood zones: delineation, description and livelihood-based demand	http://www.fao.org:80/geonetwork?uuid=dabc5510-88fd-11da-a88f-000d939bc5d8
Global Map of Aridity	FAO	2009	United Republic of Tanzania	Livelihood zones: delineation, description and livelihood-based demand	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Population density	GRUMP CIESIN	2010	United Republic of Tanzania	Livelihood zones: delineation, description and livelihood-based demand	
Livelihood zone map	FEWS-NET, USAID		United Republic of Tanzania	Livelihood zones: delineation, description and livelihood-based demand	
Soil properties (alluvial soils)	Harmonized World Soil Database v1.1, FAO/IIASA/ISRIC/ISSCAS/JRC	2009	West Bengal	Biophysical suitability: Rural electrification	

(Continued)

Name	Source/provider	Year (publication)	Country applied	Purpose	Link to download
Night lights	DMSP v.4 NOAA	2010	West Bengal	Biophysical suitability: Rural electrification	
Agricultural area	GLC2000, JRC	2003	West Bengal	Biophysical suitability: Rural electrification	
Soil properties (alluvial soils)	Harmonized World Soil Database v1.1, FAO/IIASA/ISRIC/ ISSCAS/JRC	2009	West Bengal	Biophysical suitability: Diesel subsidies	
Night lights	DMSP v.4 NOAA	2010	West Bengal	Biophysical suitability: Diesel subsidies	
Population density	GRUMP CIESIN	2010	West Bengal	Biophysical suitability: soil and water conservation - in-situ water harvesting	
Length of growing period	GAEZ v.3, FAO/IIASA	2011	West Bengal	Biophysical suitability: soil and water conservation - in-situ water harvesting	http://www.fao.org/nr/gaez/ data-portal/en/
Groundwater yield by block	West Bengal govt		West Bengal	Biophysical suitability: soil and water conservation - in-situ water harvesting	
Basics statistics by block	West Bengal govt	2005	West Bengal	Livelihood zones: delineation, description and livelihood-based demand	
Rainfall (yearly, average 1961-1990)	FAO, based on CRU dataset	2000	West Bengal	Livelihood zones: delineation, description and livelihood-based demand	http://www.fao.org:80/ geonetwork?uuid=dabc5510-88fd-11da-a88f-000d939bc5d8
Land cover	ZARI (Zambia Agricultural Research Institute)		Zambia	Biophysical suitability: Inland valley-bottom rice	
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	Zambia	Biophysical suitability: Inland valley-bottom rice	
Agricultural area	GLC2000, JRC	2003	Zambia	Biophysical suitability: Low-cost motor pumps	
Fluvisols/gleysols (inc. gleyic subunits)	Harmonized World Soil Database v1.1, FAO/IIASA/ISRIC/ ISSCAS/JRC	2009	Zambia	Biophysical suitability: Low-cost motor pumps	
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	Zambia	Biophysical suitability: Low-cost motor pumps	
Global map of yearly runoff	FAO	2010	Zambia	Biophysical suitability: Low-cost motor pumps	

(Continued)

Name	Source/provider	Year (publication)	Country applied	Purpose	Link to download
Distance to surface water	FAO, based on Hydrosheds and GLWD		Zambia	Biophysical suitability: Low-cost motor pumps	
Gridded Livestock of the World	GLW, FAO	2011	Zambia	Biophysical suitability: Small dams	http://www.fao.org:80/geonetwork?uuid=c6f03530-f317-11db-9a22-000d939bc5d8
Global Map of Aridity	FAO	2009	Zambia	Biophysical suitability: Small dams	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Global Map of Aridity	FAO	2009	Zambia	Biophysical suitability: Community river diversion schemes	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Distance to rivers	FAO, based on Hydrosheds		Zambia	Biophysical suitability: Community river diversion schemes	
Travel time to major cities. A global map of accessibility	Nelson, JRC	2008	Zambia	Biophysical suitability: Community river diversion schemes	
Global Map of Aridity	FAO	2009	Zambia	Biophysical suitability: Soil and water conservation	http://www.fao.org:80/geonetwork?uuid=221072ae-2090-48a1-be6f-5a88f061431a
Agroecological zones	University of Lusaka, Zambia	1996	Zambia	Livelihood zones: delineation, description and livelihood-based demand	
Slope	GAEZ v.3, FAO/IIASA, based on SRTM	2009	Zambia	Livelihood zones: delineation, description and livelihood-based demand	
Rainfall (yearly, average 1961-1990)	FAO, based on CRU dataset	2000	Zambia	Livelihood zones: delineation, description and livelihood-based demand	
Global Map of Aridity	FAO	2009	Zambia	Livelihood zones: delineation, description and livelihood-based demand	
Population density	GRUMP CIESIN	2010	Zambia	Livelihood zones: delineation, description and livelihood-based demand	

Annex 3 – AWM solutions described and analysed

Low-cost motor pumps (for surface water or groundwater abstraction)
Motorized pumps up to 5 HP that can lift and distribute water for farming practices. Their cost in Sub-Saharan Africa ranges from 200 up to 500 US$. They can irrigate a few hectares; smallholders in SSA use pump irrigation for high value crops, although they seldom exceed 1 ha of irrigated land per household. Farmers who have access to irrigation have substantially higher incomes and better food security than their neighbors who rely on rainfall. This needs a reliable method of drawing water from an available water source, whether it be a river, a reservoir, a pond, canal or groundwater.

Rural electrification for pumps
The solution would entail to reduce the cost of irrigation by providing a one-time capital cost subsidy to electrify 50% of pumps over the next 5 years in districts underlain by alluvial aquifers. This would also include a change in the electricity tariff structure to catalyze re-emergence of competitive groundwater markets, so that small and marginal water buying farmers can access affordable irrigation services.

Temporary diesel subsidies for pumps
The solution would entail the provision of a diesel subsidy to farmers owning less than 1 ha of land and no electric pumps, up to a maximum of 100 liters of diesel/ha, to help reduce t he cost of cultivation. For the 3 options a biophysical suitability and the potential demand based on livelihood conditions have been assessed and mapped and are presented further down.

Wetland rice management

- **Inland valley-bottom**
  Inland valleys are low-lying areas, including valley bottoms and floodplains, receiving runoff from hills and mountains. Through the use of water capture and delivery structures the systems provide supplemental irrigation and improve soil moisture retention. The Government has shown an interest in revitalizing its domestic rice sector to meet growing demand, reduce imports and contribute to poverty reduction and youth employment. Inland valleys are a possible low cost, high potential option.

- **Dambos development - Zambia**
  Dambos are shallow wetlands found in higher rainfall flat plateau areas or bordering rivers . They are used for grazing, fishing, seasonal cropping, and increasingly for upland rice, representing a possible low cost, high potential option.

Small reservoirs
Small reservoirs are earthen or cement dams that are less than 7.5 meters high. They can store up to 1 million cubic meters of water and sometimes have a downstream adjacent irrigation area of less than 50 hectares. Capital investment is generally externally driven and community management remains the norm.

Soil and water conservation

- **In-situ water harvesting**
  In-situ water harvesting is a variety of farming techniques which conserve rainwater in the soil. This improves the soil structure and moisture levels, which reduces the need for fertilizers and irrigation. As a result, yields and profits go up. In situ rainwater harvesting is important for staple crops and offers protection in low-rainfall years. These techniques can be quite labor intensive and need necessary capital and training.

- **Field bunding**
  Field bunding is a farming technique to conserve rainwater in the soil and reduce water erosion

that is practiced in steeper areas. The practice implies the construction of on-farm earth terraces/bounds to facilitate water infiltration in the soil. This improves the soil structure and moisture levels, which reduces the need for fertilizers and irrigation. As a result, yields and profits go up. This technique is also important for staple crops and offers protection in low rainfall years. This technique can be quite labor intensive and need necessary capital and training.

Ex-situ water harvesting

- **Water harvesting ponds (hapas) – West bengal**
  The solution would entail to rehabilitate/build small water harvesting ponds (hapas) to store rainwater and increase recharge (see section on rainwater harvesting). The introduction of "hapas" would provide many benefits including enabling farmers to cultivate previously fallow land, higher crop intensity, new crops, more livestock and fish.

- **Rewasagar model- Madhya Pradesh**
  Rewasagar are individual on-farm ponds, about 1/10 to 1/20 of land holding size, used to store monsoon rainwater and increase recharge. The solution would entail the rehabilitation/building of ponds and enhancement of their multiple uses. The introduction of "Rewasagar" would provide many benefits including enabling farmers to cultivate previously fallow land, higher crop intensity, new crops, more livestock and fish.

Community level river diversion schemes

Community managed river diversion (CMRD) schemes are a traditional irrigation method. They are usually temporary or semi-permanent dams and earthen canals that divert surface water from rivers. CMRD schemes are managed by farmers without external support. They are often characterized by poor infrastructure and water management, leading to low yields. Where river diversion schemes have been improved, the farmers earned considerably more than those in unimproved schemes.

AWM solutions applications in the different countries

Region/Country/State		Soil and water conservation		Small motor-pumps	Ex-situ Water harvesting	Small reservoirs	River diversion schemes	Wetland rice
		In-situ water harvesting	Field bunding					
Sub-Saharan Africa	Burkina Faso			X		X		X
	Ethiopia			X		X		
	Ghana			X		X		X
	Tanzania	X	X	X			X	
	Zambia	X		X		X	X	X
South Asia (India)	Madhya Pradesh		X		X			
	West Bengal			X[a]	X			

[a] Rural electrification for pumps and diesel subsidies

Annex 4 – Example of questionnaire on suitability criteria and conditions of specific AWM solutions

Soil and water conservation measures (in-situ water harvesting)
Questions

1. How do you measure success of this solution	Briefly describe indicators used (or you would suggest to use) to measure success
The number of spontaneous adopters, the increased production	

2. What factors influence success, and how?		Select all relevant factors from the drop-down list ranking them in order of importance, and briefly describe in which way it influences success		
Rank	Factor (click on cells below and select from list)	Conditions for successful and sustainable scaling-up	In which way (brief description, provide thresholds if applicable/available e.g. Requires >1200 mm/y rainfall)	How much relevant (high, medium, low)
1	AEZ	Arid and semi arid, mountainous/hilly places	In-situ water harvesting in arid/semi arid areas (ASAL): Practices to reduce water losses such as deep tillage, minimum tillage, trench farming, pitting. In hilly areas: Practices to reduce erosion like terracing, contour farming, cover crops	High
2	Rainfall	Low rainfall	Annual rainfall less than 800 mm	High
3	Topography		For terracing, it suitable for slopes more than10%; For in-situ water harvesting, should be less than 10%	High
4	Crop type	Best suited for specific crops? Specify in next column	Drought tolerant crops in-situ water harvesting in ASAL	High
5	Rainfall seasonality	Requires a specific rainfall pattern (unimodal/bimodal)?	Unimodal	Medium
6	Population density	Best suited with highly or scarcely dense areas in rural population?	Scarce dense population in rural areas	Low
7	Extension services	Best suited with agricultural extension services?	Training farmers on best soil and water management practices	Medium
8	Landholding size	Best suited for a small (0-2 ha), medium (2-5ha), large (>5ha) landholding size?	Medium	Low
9	Farmer typology	Best suited for a specific farmer typology (traditional smallholders, emerging market-oriented smallholders, commercial large-scale, pastoralists, etc.)	Traditional smallholders - Traditional practices	

3. Indicate Livelihood domains where this solution is most promising	Select from the list Livelihood domains (as displayed in the map) which, according to your experience, are best suited for this solution
Livelihood zone number	Score: high, medium, low
4	High
3	Medium

4. Comments	Write your comments here

Annex 5 - List of biophysical suitability criteria and conditions of specific AWM solutions

Country	AWM solutions	Surface water and Runoff	Shallow groundwater	Market accessibility	Livestock density	Agro-climatic	Night lights	Population density	Topography	Soil/land cover
Ethiopia	Low-cost motor pumps	<1km distance from surface water OR runoff > 300 mm/y	Presence of fluvisols/gleysols/ gleyic subunits in soil profile	High: < 4 h from markets. Low: 4- 8 h from markets.						**Agricultural area**
	Small reservoirs				High: > 30 unit/km², Low: < 30 unit/km²	High: 0.2-0.5 A.I. Low: 0.5-0.65 A.I.				**Agricultural area/rangeland**
Ghana and Burkina	Low-cost motor pumps	<1km distance from surface water OR runoff > 300 mm/y	Presence of fluvisols/gleysols/ gleyic subunits in soil profile	High: < 4 h from markets. Low: 4- 8 h from markets.						**Agricultural area**
	Small reservoirs				High: > 20 unit/km², Low: < 20 unit/km²	High: 0.2-0.5 A.I. Low: < 0.65 A.I.				**Agricultural area/rangeland**
	Inland valley rice	< 1km distance from rivers				Length of growing period > 210 days			**Slope < 2%**	**Wetlands (in addition to river valleys defined by slope and distance to river)**
Madhya Pradesh	Ex-situ water harvesting								**High: Slope < 5% Low: Slope > 5%**	**Agricultural areas; Vertisols**
	Field bunding								**High: Slope > 5% Low: Slope 2%-5%**	**Agricultural area**
West Bengal	Ex-situ water harvesting		High: Groundwater yield < 25 l/s, Low: > 25 l/s			Length of growing period < 200 days		**Density > 500 p/ km²**		**Agricultural areas: Thionic fluvisols (for seawater intrusion)**
	Rural electrification						High: night lights (grid in place)			**Agricultural areas; Alluvial soils**
	Diesel subsidies						**High: no night lights (grid not available)**			**Agricultural areas; Alluvial soils**

Country	AWM solutions	Surface water and Runoff	Shallow groundwater	Market accessibility	Livestock density	Agro-climatic	Night lights	Population density	Topography	Soil/land cover
Tanzania	In-situ water harvesting		High: Groundwater yield < 25 l/s, Low: > 25 l/s			High: 0.2-0.5 A.I. Low: 0.5-0.65 A.I.			High: Slope < 16% Low: Slope > 16%	Agricultural area
	Field bunding					High: 0.2-0.5 A.I. Low: > 0.5A.I.			High: Slope > 10% Low: Slope 5%-10%	Agricultural area
	Low-cost motor pumps	<1km distance from surface water OR runoff > 300 mm/y	Presence of fluvisols/gleysols/ gleyic subunits in soil profile	High: < 4 h from markets. Low: 4- 8 h from markets.						Agricultural area
	River diversion	< 2 km distance from perennial river		High: < 4 h from markets. Low: 4- 8 h from markets.		High: > 0.65 A.I. Low: 0.5 - 0.65				Agricultural area
Zambia	Low-cost motor pumps	<1km distance from surface water OR runoff > 300 mm/y	Presence of fluvisols/gleysols/ gleyic subunits in soil profile	High: < 4 h from markets. Low: 4- 8 h from markets.						Agricultural area
	Small Reservoirs				High: > 1 unit/km² Low: 0-1 unit/km²	High: 0.2-0.5 A.I. Low: 0.5-0.65 A.I.				Agricultural area/rangeland
	In-situ water harvesting					High: 0.2-0.5 A.I. Low: 0.5-0.65 A.I.				Agricultural area
	River diversion	<2 km distance from perennial river		High: < 4 h from markets. Low: 4- 8 h from markets.		High: > 0.65 A.I. Low: 0.5 - 0.65				Agricultural area
	Wetland rice management			High: < 4 h from markets. Low: 4- 8 h from markets.						damboos and flooded plains

Annex 6 - List of livelihood-based demand criteria and conditions of specific AWM solutions

Country	AWM solutions	Landholding size	Farmers typology	Cropping intensity	Population density	Rural poverty incidence	Groundwater	Market accessibility	Vulnerability to droughts
Ethiopia	**Low-cost motor pumps**		**Prevalence of market-oriented smallholder farmers:** This technology would imply higher production of high value crops for market sales. Therefore, this typology of farmers is considered to be more in demand of this technology		**Higher population density:** This indicates relatively higher pressures on natural resources therefore the need for intensification which is associated to this technology				
	Small reservoirs		**Prevalence of traditional smallholder farmers with relatively higher prevalence of livestock-based livelihoods:** Small reservoirs are one of the most important water sources for livestock in semi arid areas, particularly for traditional farmers that aim at stabilizing the production and improving nutrition rather than increasing production for sale			**Higher poverty rates:** this technology aims at providing water for multiple uses, i.e. cropping livestock water and domestic purposes. This multifunctional nature is crucial to contribute reduce vulnerability to shocks and increase resilience and therefore to alleviate poverty.			

(Continued)

Country	AWM solutions	Landholding size	Farmers typology	Cropping intensity	Population density	Rural poverty incidence	Groundwater	Market accessibility	Vulnerability to droughts
Ghana and Burkina	Low-cost motor pumps	**Small landholding size (< 2 ha):** This factor indicates the need for intensification which is associated to this technology.	**Prevalence of smallhoders:** This typology of farmers is considered to be more in demand of this technology		**High population density:** This indicates higher pressures on natural resources therefore the need for intensification which is associated to this technology				
	Small reservoirs		**Prevalence of traditional smallholder farmers with relatively higher prevalence of livestock-based livelihoods:** Small reservoirs are one of the most important water sources for livestock in semi arid areas, particularly for traditional farmers that aim at stabilizing the production and improving nutrition rather than increasing production for sale			**Higher poverty rates:** this technology aims at providing water for multiple uses, i.e. cropping livestock water and domestic purposes. This multifunctional nature is crucial to contribute reduce vulnerability to shocks and increase resilience and therefore to alleviate poverty.			
	Inland valley rice		**Prevalence of smallhoders:** This typology of farmers is considered to be more in demand of this technology		**High population density:** This technology is very labor-intensive and is suitable in large communities. It can thus offer employment particularly to landless people that are often the poorest. Therefore, areas with high population density and high poverty rates can be more in demand of this technology	**Higher poverty rates:** This technology is very labor-intensive and is suitable in large communities. It can thus offer employment particularly to landless people that are often the poorest. Therefore, areas with high population density and high poverty rates can be more in demand of this technology			

(Continued)

Country	AWM solutions	Landholding size	Farmers typology	Cropping intensity	Population density	Rural poverty incidence	Groundwater	Market accessibility	Vulnerability to droughts
Madhya Pradesh	Ex-situ water harvesting	**Areas with average landholding size of at least one ha:** this technology would imply having sufficient land to construct the pond. Landless farmers are then excluded. Therefore, this typology of farmers is considered to be more in demand of this technology					**Areas where groundwater resources are partially or totally depleted: Farmers residing in these areas are considered to be more in demand of this technology as they cannot make use of groundwater.**		**Areas where are more vulnerable to droughts: This typology of farmers is considered to be more in demand of this technology as water harvesting is an effective measure to cope with recurrent droughts.**
	Field bunding	**Areas with average landholding size of at least one ha:** this technology would imply having sufficient land to construct the pond. Landless farmers are then excluded. Therefore, this typology of farmers is considered to be more in demand of this technology				**Areas with limited accessibility to water and high poverty rates:** Poor farmers are often those one with limited capacity to access water, where they cannot afford to invest in expensive infrastructures to lift and distribute water. This technology is the considered suitable for this typology of farmers as it is low-cost.			**Areas where are more vulnerable to droughts: This typology of farmers is considered to be more in demand of this technology as water harvesting is an effective measure to cope with recurrent droughts.**

(Continued)

Country	AWM solutions	Landholding size	Farmers typology	Cropping intensity	Population density	Rural poverty incidence	Groundwater	Market accessibility	Vulnerability to droughts
West Bengal	**Ex-situ water harvesting**		**Prevalence of marginal farmers:** this technology would imply having sufficient land to construct the pond. Therefore, this typology of farmers is considered to be more in demand of this technology				**Areas where groundwater resources are partially or totally depleted.** Farmers residing in these areas are considered to be more in demand of this technology as they cannot make use of groundwater.		
	Rural electrification		**Prevalence of marginal and small farmers:** Farmers currently owning pumps are mainly marginal farmers. In addition, given the capital investment, farmers who own the land are considered to be more willing to invest on this technology		**High cropping intensity** is associated with this technology that implies the production of rice and high value crops for market sales.				
	Diesel subsidies		**Prevalence of marginal and small farmers** Farmers currently owning pumps are mainly marginal farmers. In addition, given the capital investment, farmers who own the land are considered to be more willing to invest on this technology		**High cropping intensity** is associated with this technology that implies the production of rice and high value crops for market sales.				

(Continued)

Country	AWM solutions	Landholding size	Farmers typology	Cropping intensity	Population density	Rural poverty incidence	Groundwater	Market accessibility	Vulnerability to droughts
Tanzania	In-situ water harvesting		Prevalence of traditional smallholder farmers: The technology also requires less investments in assets. Therefore, this typology of farmers is considered to be more in demand for this technology.					Limited market accessibility: this technology aims at stabilizing the production of mainly staple corps and reducing crop failure rather than increasing production for sale.	
	Field bunding		Prevalence of traditional smallholder farmers: The technology also requires less investments in assets. Therefore, this typology of farmers is considered to be more in demand for this technology.					Limited market accessibility: this technology aims at stabilizing the production of mainly staple corps and reducing crop failure rather than increasing production for sale.	
	Low-cost motor pumps		Prevalence of market-oriented smallholder farmers: This technology would imply higher production of high value crops for market sales. Therefore, this typology of farmers is considered to be more in demand of this technology		Higher population density: This indicates relatively higher pressures on natural resources therefore the need for intensification which is associated to this technology				
	River diversion		Prevalence of traditional and market-oriented smallholder farmers: this technology would imply higher production of rice both for household consumption and market sales. Therefore, these typologies of farmers are considered to be more suitable for this technology.						

(Continued)

Country	AWM solutions	Landholding size	Farmers typology	Cropping intensity	Population density	Rural poverty incidence	Groundwater	Market accessibility	Vulnerability to droughts
Zambia	Low-cost motor pumps		**Prevalence of market-oriented smallholder farmers:** This technology would imply higher production of high value crops for market sales. Therefore, this typology of farmers is considered to be more in demand of this technology		**High population density:** This indicates relatively higher pressures on natural resources therefore the need for intensification which is associated to this technology				
	Small Reservoirs		**Prevalence of traditional smallholder farmers with relatively higher prevalence of livestock-based livelihoods:** Small reservoirs are one of the most important water sources for livestock in semi arid areas, particularly for traditional farmers that aim at stabilizing the production and improving nutrition rather than increasing production for sale			**Higher poverty rates:** this technology aims at providing water for multiple uses , i.e. cropping livestock water and domestic purposes. This multifunctional nature is crucial to contribute reduce vulnerability to shocks and increase resilience and therefore to alleviate poverty.			
	In-situ water harvesting		**Prevalence of traditional smallholder farmers:** The technology also requires less investments in assets. Therefore, this typology of farmers is considered to be more in demand for this technology.					**Limited market accessibility:** this technology aims at stabilizing the production ofmainly staple corps and reducing crop failure rather than increasing production for sale.	
	River diversion		**Prevalence of traditional and market-oriented smallholder farmers:** this technology would imply higher production of rice both for household consumption and market sales. Therefore, these typologies of farmers are considered to be more suitable for this technology.						
	Wetland rice management		**Prevalence of traditional and emerging smallholder farmers:** The approach requires low investments in assets. At the same time rice cropping can improve nutrition standards and can generate surplus for market. Therefore, both the typologies of smallholders can be considered to be more in demand for this technology.			**High poverty rates:** This technology is very labour-intensive and is suitable in large communities, offering employment particularly to landless people that are often the poorest. Therefore, areas with high poverty rates can be more in demand of this technology.			

Annex 7 – Investment costs: calculations and assumptions

The calculation of the costs reflects a series of assumptions, some general and encompassing all AWM solutions, other specific to a given solution.

General assumptions:

The investment costs only encompass the initial investment for infrastructure development and do not include operation & maintenance costs.

Specific assumptions:

Small motor pumps:

The assumption is that a household is able and willing to adopt one pump and can irrigate from 0.4 (only in India) up to 0.8 ha. The number of beneficiaries households is then multiplied by the unit cost of the pump in the specific country.

River diversion schemes:

The assumption is that a household is able and willing to adopt one pump and can irrigate an average of 1 ha. The amount of potential application area is then multiplied by the unit cost of the river diversion scheme in the specific country.

Water storage (small reservoirs and water harvesting ponds):

The cost is expressed per volume of water stored. Available runoff has been considered as the starting point to assess the amount of water that could be stored in the suitable areas of the different livelihood zones. As a baseline assumption, it has been established that the potential area for application of AWM options should not exceed more than 30 percent of the annual runoff (see section on hydrological constraint for details). An upper limit would apply to potential application area, should the total volume of stored water exceed 30 percent of total annual runoff.

- For water-harvesting ponds the calculation has taken into consideration additional assumptions. These have been defined on the basis of expert consultation and literature review:
  - For each hectare of area allocated to water harvesting it is assumed there are approximately 30 000 m^3 of water stored.
  - In Madhya Pradesh, the land allocated for water harvesting is calculated as 1/15 of the number of potential benefitted households multiplied by the state average landholding size.
  - In West Bengal, the land allocated for water harvesting is calculated as 10 percent of the number of potential benefitted households multiplied by the country average landholding size.
  - Then, for both small reservoirs and water-harvesting ponds, the potential investment costs have been calculated in each livelihood zone multiplying the 30 percent of the available runoff in the suitable areas by the unit costs express in United States dollars per cubic meters of water stored.

Soil and water conservation

The hydrological constraints have not been assessed as the potential impacts on annual renewable water resources are minimal. The investment costs have been calculated by multiplying the potential application area by the unit cost per hectare.

Inland valley-bottom wetland rice

The hydrological constraints have not been assessed as the potential impacts on annual renewable water resources are minimal. The investment costs have been calculated by multiplying the potential application area by the unit cost per hectare.

In many countries, investments in agricultural water management are seen as a key element of rural development and poverty reduction strategies, but they are often costly. Planning such investments requires a good overview of their benefits and costs, and of their sustainability, and guidance is needed in answering the following three questions: i) where to invest? ii) who will benefit? iii) what typology of investment is most appropriate?

This report describes a methodology to conduct rapid country-level appraisals of the potential for agricultural water management investments in support of rural livelihoods. The approach focuses primarily on people and development, matching demand with bio-physical resources. An expert-based, participatory appraisal, combined with a national-level GIS analysis, provides a straightforward and visual description of opportunities for investments. The use of scenarios allows users to assess the costs and impact of different investment options, prioritize areas for interventions and understand the poverty-reduction potential of different types of agricultural water management interventions.

For more information consult the project website http://awm-solutions.iwmi.org or the FAO Water website www.fao.org/nr/water/projects_agwatermanagement.html.

FAOWATER

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