The Republic of Sudan

Barrier Analysis and Enabling Framework For Adaptation Technologies

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This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP Risoe Centre (URC) in collaboration with the Regional Centre, Environmental Development Action in the Third World **(ENDA)**), for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein are products of the National TNA team, led by the Higher Council for the Environment and Natural resources, Ministry of Environment, Forestry and Physical Development.

Foreword

Technology Needs Assessment for Climate Change (TNA) is a project implemented by the Higher Council for Environment and Natural Resources (HCENR) in collaboration with the United Nations Environmental Program (UNEP) Risoe Centre (URC), Denmark, and supported by the Global Environmental Facility (GEF) grant financing. Project execution is assisted by a national team composed of eleven experts representing different government institutions, research centres and universities.

TNA is considered as a prospect for Sudan to prioritize technologies suitable for Sudan conditions and contribute to reducing Greenhouse Gases (GHGs) emissions and to moderate vulnerability to negative impacts of climate change; these technologies will go in line with the national development priorities of the country.

TNA also allows Sudan to come up with ideas for sound projects on appropriate technologies for both adaptation and mitigation. Hence, Sudan is considered as one of the many vulnerable developing countries around the world due to its fragile ecosystem and its livelihood which is directly affected by the impact of climate change. TNA will also contribute to the success of implementation of the United Nations Framework Convention on Climate Change (UNFCCC) as long as the developed countries take a leading role in providing financial assistance and facilitating technology transfer for developing countries.

TNA is a participatory process; it requires consultation of wide range of stakeholders during different steps of the process. Stakeholders participated in the groundwork of these studies will eventually add more to the preparation and success of the TNA as they have different views, background and experiences in climate change. Identified sectors and sub sectors for the TNA would build upon preceding studies conducted earlier such as the National Adaptation Program of Actions and National Communications.

Sudan has set many goals in its Millennium Development Goals (MDGs). Amongst the most important goals identified are eradication of extreme poverty and hunger, combating HIV/AIDS, Malaria and other diseases and ensure environmental sustainability. Conducting TNA will give Sudan a great opportunity in achieving those goals. Technologies identified through the TNA will assist remarkably in overcoming many challenges that face the country in the context of poverty, hunger, human health and environment in general.

Environment and poverty alleviation have also been recognized as the cross-cutting issues in the Five-Years Strategic Plan of the country (2007 – 2011). Sound, environmentally benign technologies are needed to be incorporated in the improvement of the environment and alleviation of poverty. The government exerts great emphasis on the improvement and development of international relations with environmental development partners, and augmenting mechanisms for benefiting from the latest research, expertise and technologies to enable the country for achieving these goals.TNA in Sudan can go beyond prioritizing technologies to practical approach to spread the use of the technologies identified, as Sudan faces many barriers in the technology transfer such as limited resources, lack of training, poor dissemination tools. In conclusion, TNA will help overcome these barriers.

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Executive Summary

The prioritization of sectors and technologies was a result of the previous Sudan's Technology Needs Assessment first report for Climate Change Adaptation where two prioritized sectors, namely Agriculture and Water Resources have been identified.The agricultural sector has been considered the backbone of Sudan's economy and socioeconomic development. This is because the majority of Sudan's lands are suitable for agricultural development, especially if suitable adaptation technologies are adopted. However, civil war, inadequate patterns of rain, increased incidences of drought and other climate change related phenomena have strengthened poverty risks among small farmers, spatially in the rural areas where all people depend mainly on farming for their livelihoods. Hence, adoption of new production technologies has been recommended to improve productivity and farmer well being.

Sudan's water resources are derived from rains, ground water, and the river Nile and its tributaries. The water resource sector has been characterized by its vulnerability to the impacts of weather and climate related events such as floods and droughts. The major problem that faces the rain-fed farmers is drinking water after the rainy season, especially during the harvest time. The majority of the inhabitants and nomadic tribes, who live far from the river Nile and its tributaries, depend solely on the fluctuation of rains which puts lives and livelihoods at great risk, particularly in rural areas. Also, water concerned bodies and inhabitants near river banks are badly in need of reliable warning systems to reduce the damage from natural disasters such as floods and droughts. Two adaptation technologies for each sector have been selected. For the agricultural sector, Improved Crop Varieties and Zero Tillage Technologies have been chosen. In addition, Rain Water Harvesting (*Haffirs*) and Seasonal Forecasting & Early Warning System (Automatic Water Level) technologies have been rated as the best technologies. The selection of all four technologies has been conducted by stakeholder consultations as discussed in the first TNA adaptation report.

This second adaptation report focuses on identifying and analyzing technology targets, barriers, and solutions for the transfer and diffusion of the four selected technologies for both agricultural and water resource sectors. The TNA adaptation team comprised of experts representing different Sudanese states and different affiliations including governmental institutions, higher education, civil society and the private sector utilized with the support of stakeholders and experts the problem tree methodology and measures to report on barrier analysis and execute the enabling framework for the above mentioned technologies. It has been found that technologies uptake and diffusion face significant barriers. Eventually, barriers for each technology have been reported and the possible measures to overcome these barriers have also been identified and analysed.

Improved crop variety is an effective technology that enhances plant productivity, improves nutritional value and tolerates environmental stresses. It can be introduced through two processes: farmer experimental trials with new varieties or the introduction of new crop species so as to diversify the crop production systems. Non-financial barriers to implement improved crop varieties technology have been detected. These include limited availability of improved seeds varieties, lack of technical know-how and shortage of technological information. Difficulties making profits from the improved crop variety technology have been reported as a market barrier. Accordingly, provisions of the information on available improved crop varieties together with a number of measures were discussed to make the improved crop varieties technology easily accessible and adoptive for the clients.

Zero tillage is a plowing method where no real plowing takes place. It is applied in a field in which the soil is disturbed as little as possible. The crop is directly planted in a stable seedbed which has not been tilled since the harvest of the previous crop. It has been noted that the zero tillage

technology increases productivity, contributes to environment conservation and makes better use of agricultural resources. Despite the positive impacts of zero tillage and its high adaptability to climate change, it encountered both financial and non-financial barriers. These include, among others, wrong perceptions by farmers that the zero tillage method unsuitable, low crop yields, poor crop quality, high costs of input and lack of government support. Unlocking capital for projects through loan guarantees and low interest loans together with other financial measures can be adapted to a successful implementation of the technology. On the other hand, ensuring the right information flow to right recipients and improvement of research facilities have been found to be useful measures to solve many barriers of zero tillage technology.

Haffirs are reservoirs in the earth to store water for drinking and irrigation purposes. This technology has been introduced to Sudan a long time ago and the state governments have constructed many *haffirs*, small dams, and water yards. However, demand for water is growing very fast. Shortage of financing funds has been considered the main problem caused by expected maintenance and lack of technical know-how. Non-financial barriers for *haffirs* include insecurity due to the risk of water collection from far distant *haffirs* and/or vulnerable areas, and water contamination that causes outbreak of diseases and mortality. Both financial and non-financial measures have been proposed for the successful application of *haffirs* technology. The Sudanese government and policy makers are encouraged to exert their efforts in funds availability and equal distribution of *haffirs* in different Sudanese regions so as to provide rural communities with water for drinking and irrigation purposes. Additionally, legal support and the dissemination of existing laws are considered as crucial rights to solve conflicts emerging from land tenure causal problems.

Automatic Water Level technology is a system that has been developed to predict the situations of storms and floods in order to minimize their negative impacts. This technology uses data logger and submersible pressure transducers. It has been designed for remote monitoring and recording of water level or pressure data. These technological interventions play an important role in countries like Sudan which are susceptible to floods but have poor infrastructure. Awareness programs and technical know-how are considered key tools to overcome the barriers against this technology.

It is noteworthy to mention that all four technologies suffer lack of funding as the main financial barrier. Non-financial barriers that are found to be common between the investigated technologies are lack awareness, technology gaps and lack of technical know-how. Linkages between technology barriers and measures within the same sector are also discussed and reported.

Chapter I

Agriculture Sector

1.1 Preliminary Targets for Improved Crop Varieties Transfer and Diffusion

The rate of adoption of a new technology is subject to its profitability, degree of associated risks, capital requirements, agricultural policies, and socioeconomic characteristics of farmers. Producers benefit from the adoption of new technologies through opportunities to lower their production costs, either by increasing outputs from the same inputs or by maintaining the same output from reduced inputs. One of the short-term, impacts of a new agricultural technology is an increase in the incomes of farmers adopting the technology.

For the improved crop varieties technology, all the farmers of the country, rain-fed and irrigated agriculture, are preliminary targets for the transfer and diffusion of the improved crop varieties. The estimated number of the two categories is 800 000 farmers, of which 150, 000 are small-scale farmers and 650, 000 large-scale farmers. The project of Sudan's TNA focuses on small-scale farmers (150 000 farmers) as large-scale farmers are believed to be financially capable of adopting the technology at their own expense. Therefore, Sudan's TNA focuses on those who are financially incapable of adopting the technology at their own expense mainly due to their vulnerability to climate change and acute poverty. The majority of this group (small-scale farmers) is practicing farming for subsistence needs. More specifically, this includes all rain-fed agriculture in Gedarif, Kassala, North Kordofan, North Darfur, White Nile and Sinnar states. These states are stretching from the border with Ethiopia in the east to the border with Chad in the west, falling within the semi-arid and low rain savannah zones. It is true that the proposed area covered in the project is incredible and covering six states, but widespread adoption of new production technology is expected to have important market-level effects. This means that widespread adoption of a new technology is likely to have economic implications beyond the production system. The following figure presents a visible productivity improvement for watermelon in Sudan. Since the number of the target group is relatively big (150,000 farmers), it is expected to cover all the areas within ten years following the implementation of a pilot project in a selected state. In the following years different extension methods, including field days, tours and demonstrations of results and methods will be deployed to disseminate the information regarding improved crop varieties in order to enhance the transfer and diffusion of technologies in the six states. Since the Ministry of Agriculture is the responsible institution to secure satisfactory crop production, it is the responsible body for sensitizing and mobilizing small-scale farmers to adopt the technology of improved crop varieties to reduce their vulnerability.

Figure 1: Productivity Improvement of Watermelon

As far as zero tillage is concerned, the preliminary target group includes all small-scale farmers in areas characterized by 600mm rainfall per year because this is a prerequisite for the application of zero tillage. The plan covers 5,000 small-scale farmers in the following areas: south Sinnar State, Blue Nile State, South Kordofan State, southern parts of North Kordofan State and Gedarif State. Within ten years it is expected that this technology would be adopted by all the small-scale farmers. The Ministry of Agriculture is responsible for information dissemination about zero tillage and also skills training for zero tillage in all the above mentioned areas.

1.2 Barrier Analysis and Possible Enabling Measures for Improved Crop Varieties

This section provides an analysis of barriers that impede the uptake and diffusion of the improved crop varieties technology by small-scale farmers in the semi-arid zone of Sudan. The step of identifying barriers for improved crop varieties was followed by screening classifying the barriers into key versus non-key barriers, and barriers that cannot be removed or resolved. The national team through consensus arrived at determination of the final set of key barriers. Furthermore, four levels of decomposition were deployed to identify barriers that include key barriers within broad barriers, elements of barriers and dimensions of barriers. The process involved regular discussion meetings by the national team and sporadic interviews with the stakeholders according to their availability. The stakeholders represent experts from the two selected sectors, from different affiliations, i.e. governmental institutions, higher education, civil society, and private sector.

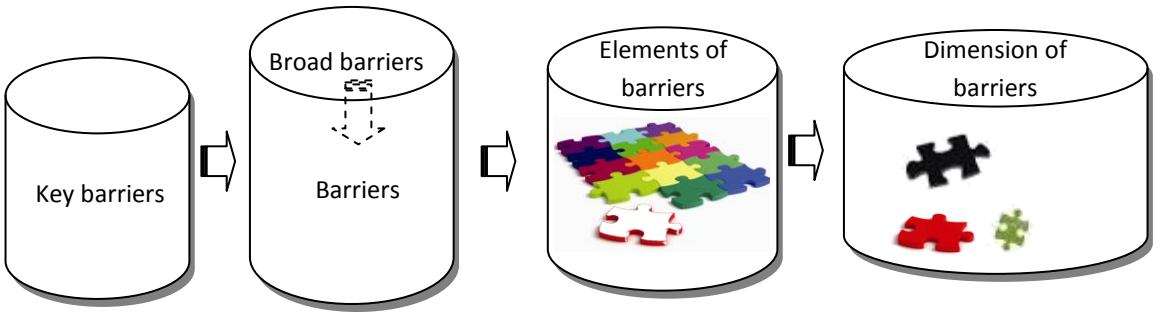

Figure 2: Identification of Barriers

The problem tree of improved crop varieties in appendix I show the decomposition of barriers. Although a wide array of adaptation options are available more extensive adaptation options are required to reduce vulnerability to climate change. There are barriers, limits and costs that are not fully understood. There is high confidence that there are viable adaptation options which can be implemented in the agriculture sector at low costs and/or with high cost-benefit ratios. Empirical research also suggests that higher cost-benefit ratios can be achieved by implementing some adaptation measures at an early stage rather than retrofitting long-lived infrastructure at a later date. In brief, it is very important to identify the barriers and analyze them to enhance the proper selection of the technology based on sound arguments.

1.2.1 General Description of Improved Crop Variety Technology

The new improved varieties of crop embody a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Plant breeding provides new improved crop varieties with unique characteristic that are beneficial, profitable and adaptable for many growing environments. The farming sector in Sudan includes a diverse mix of farmers from small holder farmers, to large-scale producers in irrigated and rain-fed areas. The production per unit area is very low due to the lack of agricultural technologies including improved varieties. Rainfall fluctuation, pest and diseases lead to low productivity. The technology of breeding new improved crop varieties depends on genetic crop diversity and crop gene resources adapted to the targeted areas. The process is composed of the following:

- Selection of the areas and local varieties adapted to the area
- Breeding process for tolerance to adverse environmental conditions such as drought, flooding and heat
- Resistance to diseases and pests
- Agronomic traits affecting yield quality, competences against weed
- Meet the need of farmers and end users
- Evaluation started during the breeding process and continues through variety release
- Testing process for environmental adaptation and farmer acceptance
- Breeding seeds production for released improved variety

To apply the technology of improved crop varieties in the rain-fed area of the country, the following requirements are needed:

- Technical skills and institutional organization
- Consultancy in designing the breeding programs of improved varieties with national and international organizations
- Technical training for researchers, states and federal staff who are working with the agriculture extension
- Establishment and rehabilitation of research units

The potential covers the main rain-fed areas in south Gadarif, Kassala, south White Nile and Blue Nile, North Kordofan and North Darfur states, and can be extended from east to central and west of Sudan.

1.2.2 Identification of Barriers for Improved Crop Varieties

Improved crop varieties are consumer goods which are specifically intended for the mass market, households, businesses and institutions. The market characteristics of improved crop varieties include a high number of potential consumers, interaction with existing markets and requiring distribution, maintenances and installer networks in the supply chain, large and complicated supply chains with many actors, including producers, assemblers, importers, wholesalers, retailers and end consumers (Shaxson *et. al*., 2008).

Farmer experimentation using only native varieties can limit the range of benefits and responses that may be found amongst the materials being tested, although local adaptation and acceptance are ensured. One of the major problems that can arise with the introduction of exotic species is the outbreak of pests. There are several examples of introduced species that have escaped control becoming pests or agricultural weeds (Ojasti, 2001). A limitation of crop diversification is that it may be difficult for farmers to achieve high yields in terms of tons per hectare given that they have a greater range of crops to manage (Hall, 2003). Farmers also face risks from poor economic returns if crops are not selected based on a market assessment. Furthermore, lack of financial funds for agricultural research leads to limited budgetary allocations for research and development. Thus, it is essential to develop more sustainable research with appropriate integration of technology adaptation and to strengthen farmer seed research companies, extension agents and policy makers (Ojasti, 2001).

After the stakeholder consultations and based on the national team's knowledge the main barriers confronting the development and adoption of improved crop varieties through breeding were identified and categorized. Appendix I shows the problem tree for improved crop varieties. The main barriers are:

- **Information and awareness:** There is a low level of awareness and perception of improved crop varieties among farmers Agricultural extension in Sudan is not efficient as there are no systematic programs and services for awareness development. In addition, all the programs are sporadic which is reflected in the low level of adoption of new crop varieties. The barrier of farmer's perception is also associated with extension services.

Farmers are reluctant to make changes in their habits and traditions and habitually follow practices carried out by their ancestors. This is a cornerstone barrier against adoption of improved crop varieties, a barrier that has substantial social and cultural dimensions.

- **Human skills:** This barrier is also associated with efficiency of extension services and lack of technical know-how. Training, particularly through demonstration, is a vital means for the transfer of technical know-how from the research stations to the farmers. Failure of transferring knowledge reduces the number of skilled farmers who are capable of producing the improved crop varieties, consequently there is a limited number of improved crop variety providers.
    - **Infrastructure:** In Sudan research stations are often characterized by limited infrastructure and shortage of technological information. Most researches in the field of improved crop varieties are confining to researches leading to academic degrees, including Master and Doctor of philosophy. Necessary equipment, particularly pertaining to crop physiology, is very expensive and unavailable which also contributes to the explanation of why only a limited number of crops have been improved. The developing counties typically lack access to information; they are not aware of what technologies fit their conditions and where they can find suitable ones. Thus, international technology exchanges are helpful for overcoming this obstacle.
    - **Cultural and social difficulties:** Changing food habits is one of the barriers, even to testability; and palatability of certain types of food may make rural people reluctant to divert to improved crop varieties.

By exploring the barriers for improved crop variety technology transfer and diffusion, the barriers can be classified into two broad categories, namely: economic and financial barriers, and non-financial barriers. The former deals with costs and tangible benefits; the latter includes cultural and social factors such as state of knowledge and skills, as well as awareness and perception. Table 1 shows the economic and financial and non-financial barriers.

The effects of these barriers is reflected in the limited use of improved crop varieties, in particular seeds or seedlings, simply because the improved varieties are out of reach of the small-scale farmers due to their high costs of application and the consequences of adoption. This limited availability of improved crop varieties in turn leads to low yields. This phenomenon is now very common in the low rain savannah and semi-arid zone of Sudan. The productivity of the agricultural land declined sharply and the only available strategy to cope with this situation is to expand the cultivable area in order to harvest the same amount the farmer used to harvest from smaller lands. The negative consequence of this strategy is represented in the huge efforts exerted by the farmers and their families (labor force) and the time spent to cover the different agricultural activities in small fragmented agricultural parcels or devastated areas. The lack of financial resources, limited availability of improved seeds and low yield automatically translates into food insecurity which may lead to instability of rural communities as they resort to transitional or permanent migration, or suffer worsening poverty. It is worth noting that this situation may lead to children malnutrition and high mortality rates of children below the age of five.

Table 1: Barriers to improved crop varieties in the Sudan

Economic and financial	Non-financial
High cost of local production	Limited availability of improved seeds varieties
High price of seeds/seedlings	Farmers awareness about existing technologies
Absence of financial facilities	Limited producers
Difficulty making profit	Farmer's perception of technology
Absence of related infrastructure	Lack of technical know-how
Limited availability of financial resources	Cultural/social difficulties
	Limited use of seeds

1.2.2.1 Economic and Financial Barriers for Improved Crop Varieties

The biggest barrier for technology transfer among developing countries may be the shortage of financial support, as appeared in the case of the Sudan. Technology recipients need new investments to adopt new technologies. The providers need to ensure human and financial resources to transfer the technology. The extent of technology transfer may be limited by the shortage of financial resources. Additional financial resources may need to be accompanied by the removal of institutional barriers in order to be effective such as cost-sharing which may be an important safeguard. According to the Food and Agriculture Organization of the United Nations (FAO, 1990), technology transfer in developing countries involves some 550,000 staff, most of them in public extension services which costs about US$4.5 billion annually. Under the influence of structural adjustment and declining public funding, extension services have tended to shrink in recent years. One of the serious barriers is the absence or paucity of financial facilities, a situation that contributes dramatically to increment in the cost of production, which in turn leads to price increases for seeds and seedlings. Governments and international organizations have the opportunity to encourage the private sector to promote effective modalities for access and transfer through grants and concessional loans. Moreover, operational budgets per researcher in the country have been declining in recent years.

Cost-benefit analysis for facilitated improved crop varieties technology taking sorghum as an example:
Objective of project is to produce improved varieties of sorghum that cultivate 100,000 feddan and grow by 10 per cent annually.

- Use zero tillage to produce a breed seed
- Seed rate /feddan=20kg. So to produce seeds that cultivate 100,000 feddan in a pilot farm of 1,333 feddan, with average production of 15 sack/feddan
- Operating costs= operating expenses + production cost + unforeseen expenses (750,000 +85,333+ 540,000) = 1,375,333 USD
- Costs of sack of seeds= 69 USD
- Current market price/sack = 24 USD
- Subsidy proposed to sell improved seeds at current market price = 24 USD
- Cost of subsidized seeds/ feddan= 39 USD

The capital costs of adaptation improved crop varieties includes one unit comprising of two offices, meeting room, laboratory and rest house for 6, 000, 000 USD, laboratory equipment costing 1, 500, 000 USD, and capacity building and training for about 500, 000 USD). The total cost is 8, 000, 000 USD, and the operating

costs of improved crop variety is about 1, 375, 333 USD. The breakdown of the operation cost is: operating costs (750 000 USD), unforeseen costs (540 000 USD), and production cost 85 000 USD bearing in mind that production costs per feddan is 64 USD.

According to available data, it is well known that the productivity of the traditional farm seeds is three sacks per feddan, while the productivity of the improved sorghum varieties is eight sacks per feddan. Therefore, using improved crop varieties saves the use of five sacks. As far as returns from the improved crops are concerned, table 2 shows returns of conventional, improved and effect of adaptation to the technology.

In addition, table 3 illustrates three scenarios of traditional, improved varieties and subsidized crops, thereby reflecting:

- Financial analysis undertaken for three scenarios to clear cut the financial impacts of adaptation technology of improved crop varieties
- Comparison between three scenarios per feddan costs
- Costs extracted from the research station costs by converting all costs per feddan
- For traditional scenario, capital costs are 10 per cent, supposed to derive net present value.
- Initial investment costs for both improved crop varieties without subsidy and subsidized scenario extracted from station capital costs
- Pilot farm to produce improved varieties of 1,333 feddan

Table (2) Returns of conventional, improved and effect of improved crop varieties adaptation technology

item	Price sack $	Area	Conventional productivity	Improved productivity	Effect
Sorghum	24	100,000	3	8	5
Returns of effect			7,200,000	19,200,000	12,068,966

Returns Annual growth 10%
Operating costs growth rate 15%
Production costs 65% of returns.

Table (3) Three scenarios of traditional, improved varieties and subsidized scenario.

Item / year	0	1	2	3	4	5	6	7	8	9	10
Traditional cultivation of dura											
Net cash flows	(8)	50	50	50	50	50	50	50	50	50	50
Present value @15%	(8)	43	38	33	29	25	22	19	16	14	12
Net present value(NPV)	+243										
Profitability index(PI)	31										
Improved crop varieties											
Net cash flows	(80)	114	114	114	114	114	114	114	114	114	114
Present value @15%	-80	99	86	75	65	57	49	43	37	32	28
Net present value(NPV)	+494										
Profitability index(PI)	7.2										
Subsidized improved seeds varieties											
Net cash flows	(80)	153	153	153	153	153	153	153	153	153	153
Present value @15%	(80)	133	116	101	88	76	66	58	50	44	38
Net present value(NPV)	+689										
Profitability index(PI)	9.6										

Table (4) Research station adaptation of improved crop varieties as a unit of production

Item/ year	0	1	2	3	4	5	6	7	8	9	10
Initial cost of adaptation	(8,000,000)										
Returns of effect		12,068,966	13,275,862	14,603,448	16,063,793	17,670,172	19,437,190	21,380,909	23,518,999	25,870,899	28,457,989
costs of effect		3,900,000	5,157,750	5,931,413	6,821,124	7,844,293	9,020,937	10,374,078	11,930,189	13,719,718	15,777,675
cash flow of effect	(8,000,000)	7,575,808	7,531,061	8,074,112	8,633,899	9,206,464	9,786,602	10,367,618	10,941,031	11,496,224	12,020,040
Depreciation		414,286	414,286	414,286	414,286	414,286	414,286	414,286	414,286	414,286	414,286
Net cash flows	(8,000,000)	7,990,093	7,945,347	8,488,397	9,048,185	9,620,749	10,200,887	10,781,904	11,355,317	11,910,509	12,434,326
PV @15%		6,947,907	6,007,824	5,581,259	5,173,329	4,783,213	4,410,125	4,053,317	3,712,073	3,385,710	3,073,575
NPV	+39,128,333										
Profitability index (PI)	4.9										

The financial barriers for improved crop varieties are mainly:

- **Financial and economic:** Lack of or limited availability of financial funds for agricultural research leads to limited allocation of budgets for research and development. Almost all the other barriers have a direct or indirect relation with the availability or lack of financial facilities. This is apparent in Sudan where all the states of the country suffer from marginalization due to remoteness from the seats of government. Another financial barrier is the high levels of poverty. Therefore, absence of financial facilities is considered the main barrier for development and adoption of improved crop varieties. There are limited or no funds available for making research at the agricultural research stations and academic institutions. Even when there are some improved crop varieties, the level of adoption lags far behind expectations due to lack of efficient extension services. This barrier is categorized as market failure, and can be considered as key barrier for the development and adoption of improved crop varieties.
- **Financial and economic**: High cost of local production and prices of improved seeds is another factor that is closely linked with limited financial funds. Costs of farmer experimentations are generally low, but results may only have local applicability. Capital investment will relate to the purchase of new seed varieties and labor time. Another factor is the high price of seeds or seedlings. This barrier associates directly with the prices of the improved seeds and seedlings. Since the cost of development is very high, it is logical to hike prices. Accordingly, the developed improved seeds may not be affordable and accessible to all the farmers.
- Difficulty of profit making: Market failure barrier is represented in the difficulty making profits from the improved crop variety technologies. Thus the adoption of this technology needs additional efforts raising awareness for the new products.

1.2.2.2 Non-financial Barriers for Improved Crop Varieties

National team members and the stakeholders have pinpointed a number of non-financial barriers that confront the adoption of improved crop varieties in Sudan. Some of these problems cannot be expressed quantitatively. They are compelling co-benefits that farmers desire, provided the costs are financially manageable over time. These non-quantifiable benefits are mainly institutional capacities on agricultural research which is limited in developing countries.

The main non-financial barriers for improved crop varieties, as perceived by the stakeholders, include;

- **Limited availability of improved seeds varieties**: research and development are only confining to academic and research institutions. The results of experimentations are placed on the shelves of the libraries and not disseminated to consumers or retailers or anybody in the production chain.
- **Limited farmers' awareness about existing technologies:** particularly under the prevalence of ineffective extension services and training sessions in the field of improved crop varieties

- **Limited producers:** lack of technical know-how and skills and complete absence or limiting enabling factors deter investment in the improved crop varieties.
- **Limited farmer's perception of technologies:** most of the traditional farmers are conservative. Thus, it is not easy to mobilize and sensitize them to adopt new interventions.

- · **Lack of technical know-how:** or the information gap between the new technology and the consumers which would highly restrict the dissemination of the intervention.

1.1.3 Identified Measures for Improved Crop Varieties

Enhancing the adoption of improved crop varieties across the country needs special measures for involving a coalition comprised of public and private sectors. In order to accelerate and guarantee steady transfer and diffusion of improved crop varieties through breeding, a number of measures and studies that could be taken by the government and private organizations or institutions are recommended. It is hoped that these ideas will stimulate the adoption of measures at a wide scale across the whole country wherever the validity of the technology is applicable. It was stressed by many researchers, particularly the Agriculture Research Corporation and faculties of agriculture in different universities of the country that there are many improved crop varieties from breeding in the country that remain under used or unutilized. The Department of Agronomy, Faculty of Agriculture at University of Khartoum released a considerable number of subsistence and commercial improved crops. The research team leader was awarded by the president of the country for the production of improved crop varieties. Other departments of faculties of agriculture in other universities, particularly Gezira University contributed significantly to improved crop varieties. However, the Agriculture Research Corporation is still the leading institute in the field of improved crop varieties.

To make these technologies easily accessible to clients, a number of measures have to be taken. For example, information on available improved crop varieties can be systematically compiled and made available. This can be done by networking existing databases. Other incentive measures could be to encourage suppliers to make the technologies available to users, to assess user needs and to stimulate the adaptation of improved crop varieties by users. Measures for the transfer and diffusion and adoption of improved crop varieties were identified through stakeholder consultations and the national team's own knowledge and experience. These measures are classified in two main groups, namely economic and financial measures and nonfinancial measures. Appendix I shows the measures for improved crop varieties.

1.2.3.1 Economic and Financial Measures for Improved Crop Varieties

The economic and financial measures that are necessarily considered to offset the economic and financial barriers to the improved crop varieties include provision of financial assistants to the farmers and producers of the improved crop varieties like subsidies and soft loans to encourage the small-scale farmers to adopt the new interventions. Therefore, provision of incentives, subsidies or soft loans will solve the barriers of limited funds, high costs of inputs and lack of profitable markets. Moreover, it is important to consider measures for the compensation of research and development (R&D) expenditures as an incentive to enhance research for better achievements. As mentioned in the barrier analysis, there is a limited or lack of research and development efforts to

improve the livelihood of local communities in rural areas. This is why improvement of research and development will nullify the barrier of limited or lack of researches and development. The incentives that could be considered are those that permit the R&D laboratories to retain their surplus earnings, and formulate incentive measures for their own scientists, thus providing a strong incentive for individual scientists. As far as the customers are concerned, the prices of the improved crop varieties should be within their reach. Since most of the small-scale farmers are poor, soft loans should not be linked with collaterals which are not satisfactory for the provision of soft loans. The head of the tribe or the traditional leader of the group should guarantee the debt repayment to avoid delayed provision of loans. Also, lower cost/removal of royalties should be considered through exempting small farmers from paying royalties. Moreover, provision of related infrastructure would enhance and expand the adoption of improved crop varieties.

1.2.3.2 Non-financial Measures for Improved Crop Varieties

This issue encompasses different items that necessitate the availability of enough information about the technology and considerable skills to guarantee the sustainability of the adoption of the improved crop varieties interventions. Therefore, finding solutions to the barrier of information inadequacy or information gap or even lack of skill and awareness necessitates the following:

- Establish a network of experts, develop policies to encourage and support researchers to invest in improved seeds and seedlings; capacity building of extension agencies to increase the providers of improved crop varieties. In addition, raising awareness of the people is necessary to eradicate cultural and social barriers regarding the adoption of improved crop varieties.
- Resolving all the barriers, including financial and economic, and non-financial, for improved crop varieties will expand use of seeds and seedling by the majority of farmers. As a result, there will be high yields of agricultural products which in turn will be reflected in high incomes from the returns from marketing of the improved seeds and seedlings. The ultimate result of the intended measures is the attainment of food security with better nutrition of local people and low expenditure for health.

1.3 Barrier Analysis and Possible Enabling Measures for Zero Tillage Technology

No tillage and Conservation Agriculture (CA) has initially been developed as farming methods to reduce erosion. It has been proven that with CA the erosion rates can be brought to levels below the soil formation, which makes the system in the long term sustainable. A review of human history and the fate of human civilizations through the millennia of human development on earth have shown that the survival of civilizations has directly been linked to the way they treat their soils. Each decline of a civilization was accompanied by significant soil erosion events, which today can still be geo-morphologically proven (Montgomery, 2007). The advantage of zero tillage over tillage agriculture in terms of the duration of plant-available soil moisture is clearly illustrated in the work of Derpsch *et al*, (1991), which shows that the situation with respect to soil moisture conditions in the rooting zones throughout growing-season are more favorable under zero tillage compared to tillage agriculture (Landers, 2007).

1.3.1 General Description of Zero Tillage

Zero tillage is a method of plowing or tilling a field in which the soil is disturbed as little as possible – the crop is planted directly into seed bed which has not been tilled since the harvest of the previous crop. In Sudan there are three major farming systems: irrigated agric systems, semi-mechanized systems and traditional rain-fed production systems. Subject to intensive and repeated tillage, rain-fed areas undergo organic matter diminishment at high rates, which results in diminishing crop yield (non- sustainable agric production system). The production costs increase due to degradation of soil resulting in low yields attended by lack of technologies. Zero tillage aims at making better use of agricultural resources through the integrated management of soil, water and biological inputs. It contributes to environmental conservation and to sustainable agricultural production by increasing rural farmers' productivity and incomes, thereby attenuating poverty. Zero tillage improves the soil, increases production while decreasing the costs of production. It consists of improved agricultural packages: crop residue from previous crops and crop rotation, application of herbicide for the control of emerging and non-emerging weeds (pre- and post-emergence herbicides), planting in rows and application of fertilizer in one operation by a special planter; and agricultural operation starting after the soil received 110 mm of rainfall.

The application of zero tillage production system requires knowledge and skills, and necessitates that farmers should be organized in groups or societies under the umbrella of agricultural service providers. All these things are available in Sudan and accordingly, the applicability of the technology is beyond doubts. Zero tillage has been introduced in Gadarif State since the year 2000. Training and skills development of state federal staff, stakeholders and farmers in the application of technologies of zero tillage, including plating, spraying and application of fertilizer, has taken place in this area. Moreover, skill- operators in maintenance and calibration are available and the farmers are aware about the zero tillage system.

Figure 3: Contribution of Semi-Mechanized System to Soil Degradation

Figure 4: The Effect of Zero Tillage Technology on Plants Re-productivity

1.3.2 Identification of Barriers for Zero Tillage

Zero tillage is a method of plowing or tilling a field in which the soil is disturbed as little as possible. Rain-fed areas subjected to intensive and repeated tillage undergo high rate diminishment of organic matter, which results in diminishing crop yields (non- sustainable agric production system). Zero tillage on the other hand contributes to environment conservation and sustainable agricultural production by increasing the rural farmers' productivity and incomes, thus contributing to decreasing poverty.

Conservation tillage systems offer numerous benefits that intensive tillage systems cannot match. These advantages are summarized as follows:

- Reduced labor requirements
- Time savings
- Reduced machinery wear
- Fuel savings
- Improved long- term productivity
- Improved surface water quality
- Reduced soil erosion
- Greater soil moisture retention
- Improved water infiltration
- Decreased soil compaction
- Improved soil tilt
- More wildlife
- Reduced release of carbon gases
- Reduced air pollution

Despite the positive impacts of zero tillage in improving the physical and chemical properties of agricultural soil, which is directly translated into increased crop productivity of agricultural, the practice is confronted with barriers and measures of risk that may confine its adoption to certain sites.

Table 5: Barriers confronting adoption of Zero Tillage

Economic and Financial Barriers	Non-financial Barriers
Lack of financial support	Unavailability of enough information or knowledge
Impossibility of crop rotation	Lack of know how about zero tillage
Difficulty of buying specialized machine (Small farm size)	Lack of government support
Difficulty of buying adequate herbicides	Farmer perception
Poorly developed infrastructure	Lack of adequate policies to promote adoption of intervention
High costs of inputs	Ecological barriers
Unavailability of Zero Tillage machines at markets	Poor research
	Strong demand for crop residues

1.3.2.1 Economic and Financial Barriers for Zero Tillage Technology

The costs of applying zero tillage are high compared to traditional agriculture. The analysis shows that the costs of establishing one unit with zero tillage equipment, i.e. a tractor 90HP+planter+ sprayer, is approximately 31, 600 USD, compared to the costs of cultivation of one hectare by traditional method which is approximately 40 USD. Analyses of other elements in zero tillage also revealed that lack of local production and availability of equipment and other inputs, such as herbicides, add to the significant increase in costs and may present a barrier to its implementation.

Financial barriers are the cornerstone obstructing adoption, success and sustainability of zero tillage. Therefore, during group consultations measures were proposed to overcome zero tillage barriers in the short and long run by using logical problem analysis. The following frame denotes how sequentially different measures can contribute to alleviating such barriers that lead to the successful adaptation of zero tillage. Such measures predominantly rely on a conceptual framework of cooperative activities, including:

- Clustering small farmers into cooperative societies
- Bank finance
- Specialized pool finance
- Extension efforts
- Pilot farm is very impressive on farmers

Assumptions used for the cost-benefit analysis are:

- Exchange rate of 1 USD=SDG 5.8
- Unit farm of 1933 feddan
- Production costs grow annually by 15 per cent
- Sales grow annually by 10 per cent
- Extension services and pilot farms: 1 USD/ feddan for only two years 1 USD/ feddan

- Maintenance costs: 3 per cent of production costs
- Lubrication: 1 per cent of production costs
- Costs estimated based on feddan for financial analysis calculations

Cost items include 1\ Capital initial costs

- Cooperative formulation: procedures to register societies cost 3, 000 USD
- Production unit should be dedicated to one tractor
- Tractor could achieve cultural practices as planting, spraying fertilizers, pesticides and herbicides
- Each unit of 1933 feddan should have one tractor with its accessories., i.e. tractor + its accessories= 31,600 USD
- Pilot farm of one feddan incurs a production cost of 64 USD per unit
- Total initial investment costs=(3, 000+31 600+64)= 34, 664 USD

Table (A) in Appendix I denotes capital and operating costs, and the effects of adaptation technology. The benefits of adopting zero tillage technologies include increases of crops yield per unit area, preserving soil and decreasing erosion. The cost assumption for the analysis includes; current traditional cultivation yield per feddan in rain fed =4 sack, adaptation effect a yield of 10 sacks, price per sack= 21 USD, and initial investment share per feddan = 64 USD.

Table 6: Net Present Value of Adaptation of Zero Tillage Technology

Year	0	1	2	3	4	5	6	7	8	9	10
Traditional yield sack/feddan)		4	4	4	4	4	4	4	4	4	4
Adaptation Tech yield(sack/feddan)		10	10	10	10	10	10	10	10	10	10
Adaptation effect		6	6	6	6	6	6	6	6	6	6
Adaptation benefits $/fed	-64	126	152	168	184	203	223	246	270	297	327
Adaptation Costs		104	120	138	158	182	209	241	277	318	366
Net benefit		22	22	22	22	22	22	22	22	22	22
PV @15%	(64)	110	95	83	72	63	54	47	41	36	31
NPV	+15										
Profitability index(IP)	1.24										

- **Discount rate adopted 15 per cent, represents capital cost imposed by the Central Bank of Sudan, monetary policy for 2013.**

The financial analysis parameters used are profitability index and net present value and calculation of net present value to pinpoint financial feasibility of the adaptation effect created by adoption of zero tillage technology. Table 6 shows the net present value of adaptation of zero tillage technology.

The main economic and financial barriers confronting transfer and diffusion of zero tillage practices are:

- Soil degradation and weed mismanagement
- Difficulty of buying specialized machine
- Lack of financial support
- High costs of inputs and implementation which makes crop rotation impossible
- Difficulty of buying adequate herbicides

1.3.2.2 Non-financial Barriers for Zero Tillage

The main barriers of adoption of zero tillage are: (1) lack of locally-appropriate knowledge and/or poor research and development for conservation tillage technologies (2) high investment technology in rain-fed areas (3) depending on rainfall which is a most unpredictable variable (4) mindset (tradition, prejudice) (5) lack of adequate policies (6) availability of adequate machines (7) prevalence of small landholdings and (8) unavailability of suitable herbicides to facilitate weed management. Ecological barriers to zero tillage production systems include low precipitation with low biomass production, short growing seasons and soils at risk of water logging. Socio-economic constraining factors include strong demand for crop residues as forage for livestock, uncertain land use rights and poorly developed infrastructure (market, credit, extension service). It has also been stated that zero tillage poses many new management challenges for the new farmers who are familiar with traditional types of agriculture. If farmers never witnessed the practice of zero tillage through demonstration method or demonstration of results it would be very difficult to adopt the intervention. In Sudan, this is not easy to be achieved due to the lack of efficient extension services. This verifies why lack of know-how represents a corner stone for the adoption of the zero tillage method. The social pressure which is represented in the urgent need of the agricultural residues for different uses (traditional building mulch and a source of fuel) represent a real challenge for the adoption of zero tillage. This pressure is in line with the lack of awareness which needs special consideration.

In Sudan, due to the misconception that the zero tillage soils are degrading at an alarming rate skirmishes between individuals develop into conflicts between tribes and finally escalate into political power disputes as in the case of the Darfur crisis.

1.3.3 Identified Measures for Zero Tillage

Barriers confronting the adoption of zero tillage must be overcome by politicians, public administrators, farmers, researchers, extension agents and university professors. These are very important for Sudan in order to transfer and adopt the technology of zero tillage. With adequate policies to promote zero tillage, it is possible to obtain what is called the triple bottom line of

economic, social and environmental sustainability, while at the same time improving soil health and increasing production (Friedrich *et. al*., 2009; Friedrich and Kassam, 2009). Therefore, in order to have a right measure to abolish the barrier of the lack of adequate polices, investment must be made to ensure sufficient and sound research and efficient extension services, all of which requires governmental commitment to adopt the intervention through sound and effective polices. This coincides with what Friedrich *et. al*., (2009b) proposed. Accordingly, researchers and extension personnel need to reflect on the benefits of no-till farming systems. Farming systems should foster research and development efforts in order to overcome the bottlenecks of the system and help extension personnel in diffusing the technology so that farmers can have a sound basis for practical application.

Through various discussions and consultations, the national team and the stakeholders identified measures to overcome the barriers against zero tillage diffusion. These measures are classified as economic and financial measures, as well as non-financial measures. The former are those which take place when any changes in prices and quantities are assumed to be attributable to the imposed changes resulting from technology adoption. They can be translated into measures of economic surplus change, which are allocated to producers and consumers according to the supply and demand elasticity. The latter are usually intangible measures which cannot be classified into quantitative data including policies, legislation, awareness, or knowledge.

1.3.3.1. Economic and Financial Measures for Zero Tillage

The main economic and financial measure for zero tillage technology is availability of finance which can take different forms like subsides, incentives and soft loans. Sudan is one of the least developed countries with high levels of poverty. All the governmental institutions are under staffed and underfunded. Moreover, due to the civil war and the war with South Sudan, agriculture is not a top priority for the government. Therefore, incentive measures could be introduced to encourage suppliers to make the technology available to users through conducting a survey to assess user needs and to stimulate the adoption of zero tillage by users containing specific provisions regarding legislative, administrative or policy measures for access to and transfer of technology. Subsidies are not working in Sudan because the Ministry of Agriculture is always underfunded under the economic embargo imposed on the country for more than two decades. Despite these complications in the country, soft loans are a possible means for solving the constraints and measures of risks confronting the diffusion and transfer of zero tillage technology. The private sector can be mobilized to play the role of the donor to enhance agricultural productivity. Unlocking capital for projects can be achieved through loan guarantees, low interest loans or innovative recoupment structures. Another measure that has a direct relation to the financial measure is the guarantee of inputs and necessary equipment to enhance the adoption of technology.

1.3.3.2 Non-financial Measures

Good program design and delivery are critical to ensure that the complementary measures in the zero tillage packages deliver their full potential for adaptation to climate change and variability. It is essential that lessons are learned from previous efforts to ensure that programs meet their needs in overcoming barriers. Information on available zero tillage could be systematically compiled and made available to farmers through efficient extension services of the Ministry of Agriculture and Animal Resources. In Sudan the level of illiteracy is very high. Therefore, brochures, pamphlet

and handouts are of no use and only service a small proportion of the small-scale farmers. The best method for dissemination of information is through individual or group extension methods. The mass media extension method is of limited use due to illiteracy. The importance of this step is to fix any misunderstanding or cultural and social barriers that confront the adoption of the technology. Through awareness raising any misconception will be checked. This will give fruitful results if targeted programs reach the right people to encourage the adoption of zero tillage. On the other hand, improvement of research through support of research and academic institutions would solve many of the barriers to zero tillage adoption. Finally, existence and availability of skilled labor is of paramount importance in creating an enabling environment for solving the barriers and attainment of good results. If all the measures were guaranteed the result will be the improvement of soil structure and the control of weed will be well managed. This will take place if specified budgets are allocated for these measures. The short-term results of the measures for zero tillage are exemplified in high yield per unit area, efficient land use, rehabilitation of natural rangelands, prevalence of peace, reduction of livestock mortality, cheap food prices and decrease of vulnerability to food insecurity will be guaranteed. In the long term the results will be alleviation of poverty.

1.4 Linkages of the Barriers Identified in the Agriculture Sector

For improved crop varieties the barrier of lack or limited availability of financial funding has two dimensions. The effect on the producers of improved seeds and seedlings is exemplified in the high costs of local production of improved crop varieties and for the consumer the high prices of the seeds and seedlings imposed by the producers represent a challenge to adopt the new technology of improved crop varieties. This situation invariably leads to difficulties in making profit. On the other hand, the absence of related infrastructure for improved crop varieties will automatically be translated into shortage of technological information which ultimately will be translated into lack of technical know-how. All these factors give rise to social difficulties that confront changing food habits of the local people.

As far as zero tillage is concerned, there are some barriers out of control like ecological barriers which are represented in the low precipitation, water logging and frequent drought cycles. The lack of financial support represents a corner stone in the failure of dissemination, diffusion and adoption of zero tillage technology. Lack of financial support can lead to difficulties buying specialized machines and adequate herbicides. As a result what is actually used at the field is poorly developed infrastructure. Moreover, unavailability or lack of enough information regarding zero tillage in effect perpetuates reliance on traditional methods of farming that insinuates soil degradation.

Table 7 shows the linkages of the barriers for the two technologies for adaptation of agriculture sector.

Table 7: Linkages of the Barriers for the Agriculture Sector

Market linkage - Currently no market for this technology - Products not outstanding or maintaining long-term stability - Lack of investment on infrastructure, leading to short-term, low efficiency
Enabling factor - Incentive polices for diffusion of the new technology are not strong enough - Procedures for approval or registration are usually complicated, sometimes unsuitable or unavailable to market demand - Poor infrastructure - Sustainable production is not done on voluntary basis
Support actions - Lack of support for research and development - Lack of information - Lack of project management - Limited local management capacity and expertise

1.5 Enabling Framework for Overcoming the Barriers in the Agriculture Sector

This section discusses the vital elements of the enabling framework that should be enhanced to improve the quality and efficacy of the technologies for agricultural sector transfer and diffusion. The enabling frameworks are those resources and conditions that are generated by institutions which are beyond the immediate control of the beneficiaries. In brief, the enabling framework provides the environment conducive for the transfer and diffusion of adaptation technologies for the agricultural sector. Table 8 shows the eenabling environment for the agricultural sector. The enabling framework for the agricultural technologies, i.e. improved crop varieties and zero tillage, are explored relying on six general groups, namely:

- Finance policy or market support since the lack of this variable results in or contributes significantly to the creation of the key problem
- Land registrar: In Sudan most of the lands are under customarily land tenure systems in which lands are not registered. Under such conditions the government has a limited control over the resource. Therefore, the government should enhance the registration of the lands in order to guarantee sustainability of the activities.
- Business regulation: the flow of seed crops from the producer to the clients pass through several channels. If the government has not enough control over these

channels this may result in corruption or monopoly of the activities. The same can be applied for the zero tillage. The adoption of the intervention necessitates the organization of the farmers beside their sensitization and mobilization. To deliver extension services it is important to regulate the business by knowing the number of farmers and of organizing them into working groups.

- Trade standard: the government should issue prescription for the trade standards in the different input whether for the improve crop variety or zero tillage.
- Tax and tariff: the government should encourage farmers to improve their productivity either through improved crop varieties or zero tillage, or both. This can be through exemption of royalties to enhance the import of necessary inputs.
- Consumer trend: the government can change the attitude of the farmers through extension to the extent of changing their food habits.

To make the slogan become real, the enabling framework should encompass the following measures:

- **Network of experts:** creating a network of expertise is an important medium that allows exchange of ideas and information to ensure demonstration as well as innovative and successful implementation of measures to promote strategies that include compulsory information campaign messages and raising awareness.
- **Policies and measures**: promote existing technologies transfers in countries such as Sudan that have many obstacles which need resolving by implementation and enforcement measures as well as new, rationalized policies towards new directions.
- **Change organization/behavior** usually occurs outside the market system but it is important in improving market and non-market functions. Those obstacles caused by the actual state of the current operation or organizations may request a change in the management approach.
- **Market support systems and other financial services** to ensure accountability, functionality and providing these services to achieve efficiency; taking into account that there are multiple relevant systems in one place which are supposed to translate into various financial services, quality insurance system, consultancy and information services.
- **Skills, education and training** constitute key foundation to development. Planning and investment in this area is necessary, together with other measures to bring the required skills and ensure appropriate education and training.
- **International Cooperation and IPR issues** may not be sufficient nationwide for promoting technology and required international linkage. Trade and international IPR systems need examining and the tasks under other international agreements also have influence.

The above mentioned table is applicable for the two technologies due to their similarities in terms of geographical area of application, primary stakeholders (small-scale farmers) and secondary stakeholders (Ministry of Agriculture).

Table 8: Enabling environment for agriculture sector

Enabling environment	Market actors	Category	Condition	Support services
Finance policy or market support	Government institutions	Finance	Set up support fund	National banks
Land registrar	Institutions	Policy, legal and regularity	Polices for registration	Legislation
Business regulation	Producers	Financial support	Capacity building	Training and network of expert
Trade standard	Local producers	Human skill	R & D	Finance
Tax and tariff	Institutions	Policy, legal and regularity	Minimum taxes	Policies & measures
Consumer trend	Consumer	Social	Awareness raising	Extension services

Chapter 2

Water Resource Sector

In Part I of the TNA adaptation report, two groups of adaptation technologies have been selected by the stakeholders as best and suitable adaptation technologies for Sudan's specific needs. These are *Rain Water Harvesting* (*Haffir*) and *Seasonal Forecasting* in tandem with and *Early Warning System – Automatic Water Level*. The first technology (*Haffir*) would improve the livelihood of many villages by providing clean potable water as well as water for irrigation and animals. Automatic Water Level is crucial to predict the expected situations of storms and floods in order to minimize climate change risks and enhance adaptation plans before the disaster might take place. For all water source technologies the main objectives are as follows: to increase water supply security, to build flexibility for managing all types of water supply and demand scenarios, to minimize damage from disasters, to maximize the efficiency of water usage, to include all stakeholders in water management, and to build knowledge/know-how and data for water management. Water scarcity is the single most annoying impediment for development and stability. Competition for shared natural resources, in particular water and land, is a root cause of conflict and instability. Since water is the essence of life without which life cannot be sustained, its availability is vital for any socio-economic development. Therefore, rainwater harvesting will be the entry point for socio-economic development in rural Sudan. The livelihood of the country's rural population, who live away from the Nile, depends entirely on rains. Because of its many advantages, rainwater harvesting development programs rank among the highest government strategies for rural socio-economic development. The high risk of rain-fed farming coupled with poor-resource farmers suppresses rural development, while inputs that increase crop productivity such as proper land preparation, improved seeds, fertilizers and pesticides are not used. The natural characteristics of the Sudan make rainwater harvesting an important tool to sustain life, peace and livelihood for rural communities. The main aim of rainwater harvesting is to manage the rain water from the moment it falls and ensure that it is used productively before it returns to the atmosphere by evaporation. Water harvesting may occur naturally or through intervention. The main influencing factors in water harvesting potentials are rainfall intensity, duration and distribution. Rainfall is a most unpredictable variable, runoff and catchment characteristics depend upon the area and type of the catchment over which it falls as well as surface features.

2.1 Preliminary Targets for *Haffirs* Technology

The targeted area for development relying on selected technologies for the water resource sector is geographically very large. It is the belt bounded roughly by 300 and 700 mm isohyets. It extends from central Sudan to the border with South Sudan and runs across the country from east to the west. There are no accurate figures of the pastoralists and their herds, nor farmers and their lands that are impacted by water scarcity. However, in the literature it is generally agreed upon that the rural population constitutes about 70 per cent of the total population. Contribution of farming and livestock rearing in the national economy is significant. Rain amounts are fair to quite good for rainwater harvesting development. However the problem lies with temporal and spatial distribution of rain as well as its capture and storage. The Government of Sudan has decided to embark on

water harvesting projects to initiate socio-economic development and to meet the increasing demands for water.

The prospects for rain water harvesting development are very good in the concerned regions for both pastoralists and farmers' communities. Traditional rain-fed farming in the region is usually at subsistence level. Its productivity is very poor and barely adequate to secure basic family food requirements let alone generate income. Sorghum and millet are the main staple crops with low nutritional values.

2.2 Barrier Analysis and Possible Enabling Measures for *Haffir*

Lack of financing funds is one of the most persistent impediments facing socio-economic development in the country. This is particularly so for rainwater harvesting development. Despite the difficulties facing Sudan's economy in the short run there are broad indications that the economy will improve gradually in the long run, such as stringent austerity measures, revival of the agriculture sector, gold mining and significant inflow of direct Arab and foreign investments. Improvement of the economy will lead to better livelihood prospects and services for the people of Sudan and in particular water supply and augmentation. Rainfall characteristics (intensity, duration and distribution) are most unpredictable variables. Regarding the costs, *haffirs* are of lower cost compared to dams. However, while medium and long term prospects for Sudan's economy appear bright there is no immediate prospect for funding water harvesting on the scale required.

2.2.1 General Description of *Haffirs*

Water harvesting is the capture, diversion, and storage of rain water for different uses mainly for drinking and irrigation where water becomes available to the crop and thereby enabling economic agricultural production. *Haffirs* are manmade ground reservoirs in the earth at suitable locations to store water for drinking purposes for both human and livestock. The concept is that water running in natural streams during the rainy season is diverted at certain suitable locations into these Haffirs. The size of the Haffirs ranges from 100,000 m3 for large one to 30,000 m3 for small ones. Guide bunds are required to divert the water into the *haffirs*. If it is used for human drinking filters are required to ensure clean potable water. As far as the applicability of the technology is concerned the construction of *haffir*s and their management requires skills and institutional organization, consultancy in design of the *haffirs* and its implementations and training for skills development of state staff and local communities to operate the *haffirs*. Maintenance of the water harvesting projects is one of the core requisites for sustainability.

Haffirs are widespread in different areas of Sudan. Rain water harvesting is one of the priority programs for rural socio-economic development in the country. Rain water is not only important for drinking, it is also important in agriculture and pasture as most of the livelihood of the rural people depend on farming and animal rearing. Compared to other means of development, rain water harvesting is cheap to develop with high socio-economic returns. After thorough investigations, technical experts in the country have come to the conclusion that many water harvesting techniques can be used to avail water for drinking and farming on small-scale all over the targeted area. *Haffirs*, small dams, reservoirs in natural depressions and contour bunds, inter alia, can be used. The technology is confronted by some barriers like lack of financing funds,

which is one of the most persistent impediments facing socio-economic development in the country. This is particularly so for rainwater harvesting development. Despite the difficulties facing Sudan's economy in the short run, broad indications such as stringent austerity measures, revival of the agriculture sector, gold mining and significant inflow of direct Arab and foreign investments suggest that the economy will improve gradually in the long run. Improvement of the economy will lead to better livelihood prospects and services for the people of Sudan and in particular water supply and augmentation. Rainfall characteristics (intensity, duration, distribution) constitute a perennially unpredictable variable. Regarding costs, *haffirs* cost significantly less than dams. *H*affirs are manmade ground reservoirs in earth at suitable locations to store water for drinking purposes for both human and livestock (Fig. 5).

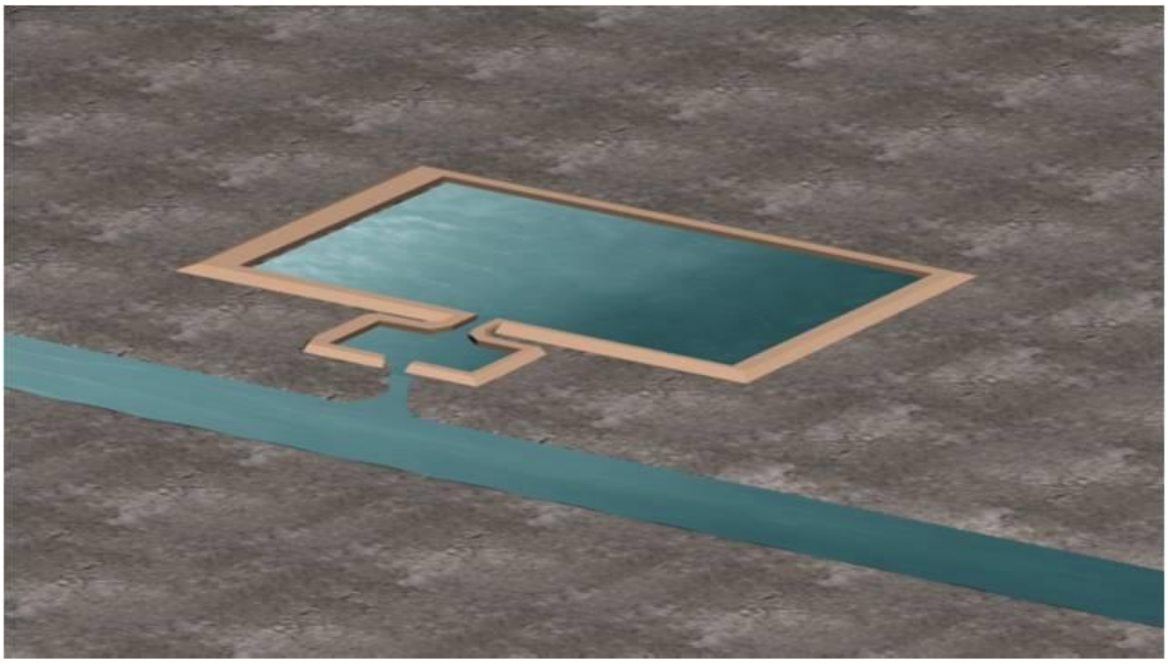

Figure 5. 3D View for *Haffirs* System, *Source: Elkhidir, 2011*

Figure 6: *Haffirs* with a silt trap – Western Sudan *Source: Sanjak, 2004*

2.2.2 Identification of Barriers for *Haffirs*

The ecological barriers are detrimental for the success and adoption of the *haffirs* and their replication. The duration of rainfall has great effect on the amount of rain water. Long duration of rainfall means high floods because of long runoff periods. This has significant effect on water harvesting. If good water harvesting techniques are used, a lot of rainwater can be stored. If rainfall is uniformly distributed within an area the runoff will also be uniformly distributed in that area. Moreover, sustainability is a crucial factor during water harvesting project implementation and after the completion of the project as well. Based on problem tree methodology, lack of financing funds is considered the main problem posing several limitations and barriers to rainwater harvesting (financial barrier). In spite of the financial barrier, *haffirs* are considered the lowest cost technology for rain water harvesting. However, there is a limited number of equipped institutions to design and implement this technology efficiently. In addition, designing and implementing *haffirs* requires regular consultations between project implementers and stakeholders, which is also considered a constraint confronting adoption. In addition, the amount of trained experts capable of regular maintenances is very limited and may lead to structural collapse and decreased water storages.

A technical and ecological problem that impedes the sustainability of *haffirs* projects is soil erosion and *haffirs* maintenance. Tillage and natural vegetation strips can be used as a possible measure to overcome soil erosion around *haffirs* boundaries. Other barriers are lack of technical know-how, land tenure, soil siltation and infiltration. To overcome these drawbacks, enhancement of knowledge and awareness, as well as additional filtration and disinfection are important to be applied. In Sudan, the implementation of *haffirs* is usually done by a national contractor and sub-contractor determined by public tender; therefore the majority of haffirs are government owned,

though some are private. *Haffirs* technology produces non-market goods. It is identified as public and the market mapping could not be created due to the lack of clear market chain and dealers.

2.2.2.1 Economic and Financial Barriers to *Haffirs*

Measures adopted for better adaptation of water harvest technology (*Haffirs*) encompass the following;

- Government intervention and subsidy for development of marginal areas and promoting productive activities
- Non-governmental organizations' contribution in social development
- Private sector involvement as part and parcel of social activities
- Zakat in rural areas should be directed to finance society's basic needs
- Experts in soil analysis
- Increase awareness and encourage cooperation between actors in different interfering activities

The cost –benefit analysis for facilitating *Haffirs* adaption is derived from the capital costs of *haffirs* and benefits extracted from the adoption thereof. The capital costs include:

- Excavation costs: one square meter costs 10 USD
- Area of moderate Haffirs of 30,000m2 size = 300,000m3
- Annual maintenance 1 USD/ m3= 30,000 USD/ year
- Soil survey and analysis cost 3 per cent of Haffirs excavation costs =9,000 USD

Benefits extracted from adoption of *Haffirs* are:

- *Haffirs* are a source of water for human and animal
- *Haffirs* supply extra water for crops in areas of short rainy seasons
- *Haffirs* existence saves life of animals and decreases mortality rate and consequently livestock loss costs by 5 per cent
- Saves life of animals by eliminating thirst, prospers nomads' economy by selling well fattened animals and flourishes processing activities of animal products such as meat, milk and skins
- Numerically, *haffirs* technology adaptation saves 5 per cent of herd loss which is a significant multiplier effect benefit.

In brief, the cost items of Haffirs are: excavation of 30,000m3 (300,000USD), and soil survey and analysis is 9,000 USD.

Benefits extracted from the adaption of *haffirs* includes: annual loss due to thirst is 5 per cent of a 5,000 head a herd; thus saved lives of 5 per cent represent a return expected from the adoption of Haffirs. So, the loss cost of mortality is about 5 per cent; lost return for mortal of 5 per cent equal price of one head which is equivalent to 155 USD. This makes a total loss saved-return of 38,793 USD. Appendix I, Table B shows returns of *haffirs* technology adoption. Table 9 shows the net present value for adaption of *haffirs* technology.

Table 9: Net present value for adoption of *Haffirs* technology

Item/year	0	1	2	3	4	5	6	7	8	9	10
Initial costs	-309,000										
Return		38,793	51,304	58,999	67,849	78,027	89,731	103,190	118,669	136,469	156,940
Present value	-309,000	38,793	38,793	38,793	38,793	38,793	38,793	38,793	38,793	38,793	38,793
NPV @15%	+78,913										
Profitability(PI)	1.3										

2.2.2.2 Non-financial Barriers

Beyond the obvious cost limitations, several non-financial barriers and limited access to water and *haffirs* water harvesting technology have been detected after the problem tree and measures. These barriers can inhibit technology adoption, efficiency of *haffirs* and sustainability of water availability from *haffirs*. They include:

- **Lack of human technical skills and scarcity of technical know-how** obstruct the implementation and the expected maintenance of *haffirs*. Biased decision on *haffir*'s location results in an inadequate distribution. This can affect the community culturally and socially. Also the cultural custom of water collection from *haffirs* by children and girls from far distances would expose girls and children to security risks.
- **Policy and regularity barrier:** Land tenure in Sudan cannot be regarded solely as a production variable but as an extremely significant element in the social structure servicing multifunctional aims and objectives. More than a factor of production, it is a tangible dimension of community and has what is called the "territorial character of community". In general, land provides community stability and centricity and it becomes more significant rather than less, in a period of otherwise rapid social and economic change. In Sudan most of the land is considered government property except the free hold land.
- **Awareness barrier**: the local people in rural areas are usually suspicious of outsiders. They always believe that the intervention of the outsiders is just a means of grasping the resources of the area. This situation creates difficulties in mobilizing and sensitizing local communities to participate genuinely in the activities of *haffirs*.
- **Social barrier** (**Insecurity in some areas)**: the civil war in Sudan almost restricts the implementation of developmental activities which also include the adoption of water harvesting techniques. Moreover, *haffirs* represents a source for natural resource-based conflicts, particularly between nomads and settler farmers.

The effects of the above mentioned barriers (financial and economic, and non-financial and economic barriers) clearly have negative consequences on the sustainable livelihood of local communities, the environment and health of human beings and animals. The impact of these barriers is exemplified in lack or shortage of water which leads to the exploitation of the same source of water by human beings and animals. There are many incidences of diseases outbreak due to this practice. In certain situations, the conflicts over water sources may escalate to intractable disputes. Under the worst situation, many communities migrate temporarily to other sites with abundant water; and in the history of Sudan some villages were displaced permanently because of water shortage.

2.2.3 Identified Measures for *Haffirs*

Based on the stakeholder consultations, interviews with decision makers, the consultants' own knowledge and international experiences, the measures to overcome financial and non-financial barriers in water harvesting and seasonal forecasting have been outlined. Building capacity, technology, and economic barriers to the technology transfer and diffusion of the technologies have been identified, which is shown in the problem trees and measure in Appendix I.

2.2.3.1 Economic and Financial Measures for *Haffirs*

Limited use of *haffirs* is associated with lack of financial support. It is well known that all the rural areas in Sudan suffer from marginalization. Many of the opponent movements in the country attribute their opposition to marginalization. Therefore, if there is a chance to allocate some money for *haffir* intervention, many of the natural resource-based conflicts might be solved. It is important to convince the policy makers to allocate funds for undertaking *haffirs* technology. This can be achieved by the national strategic development plan that allocates more than 90 per cent of the budget to sustainable development and poverty alleviation. Complementarities with the investments of Government (through the State and the Agriculture Revival Program) and other donor funded initiatives can also support the technology implementation and maintenance.

The economic and financial measures are represented in provision or allocation of reasonable amounts of money for the maintenance and rehabilitation of old *haffirs* since these *haffirs* are liable to annual siltation to the extent that any number of them could be buried completely. Thus assignment of finance is needed for improving research and development activities in the water sector; and also for provision of technical knowhow through establishment of experts' networks, as well as provision of inputs and machinery.

2.2.3.2 Non-financial Measures for *H*affirs

It is crucial to put in place the necessary measures for effective project management and implementation with incorporated measures to facilitate the replication and wider adoption of Haffir's technology. These measures include training of rural communities so that they can train their peers, develop the capacity to collaborate with common interest groups in technical and managerial skills in *haffirs* design and improve *haffir* construction and management skills; encourage and enable the private sector to provide timely services to *haffirs* in their communities and villages so as to assure sustainability of water availability in existing *haffirs* and enforce laws that sustain societies and community rights for their land tenure.

The non-financial and economic measures for *haffirs* activities are exemplified in training farmers and extension personnel. Enhancing knowledge and raising awareness, providing good or at least reasonable distribution of *haffirs* across the vulnerable sites to curtail or overcome water deficit is of vital importance to *haffirs* technology adaption. The results of the above mentioned measures can be reflected in the availability of water for domestic use and for animals. Peace will prevail at the areas of natural resource-based conflicts, migration will cease and oppositely there will be resettlement and the health conditions of the people and animals will be very good.

2.3 Barrier Analysis and Possible Enabling Measures for Seasonal forecasting and Early Warning Systems: Automatic Water Level Technology

2.3.1 General Description of Automatic Water Level technology

The Remote Sensing Technology for the receipt and processing of satellite images are used to estimate daily rainfall quantities over the catchments of the Blue Nile and Atbara rivers in Ethiopia and Sudan. A communication system transmits water levels in the Blue Nile, Atbara River and Main Nile in Sudan to the Flood Warning Center in Khartoum. A computerized Flood Forecast System, consisting of a set of mathematical models with an appropriate user interface allows smooth and rapid data processing and forecasting. The Automatic Water Level is a data logger and submersible pressure transducer combination designed for remote monitoring and recording of

water level or pressure data. The water level logger can record over 81,000 readings and has four unique recording options, fast (10 samples per second), programmable interval (1 second to multiple years), logarithmic, and exception. Multiple depth ranges are available from 3 to 500 feet of water level change. A 25 ft vented cable is standard on all water level loggers.Timely information during flood season is highly requested and will prevent loss of life and houses. Installation of automatic loggers and management of them require expert and institutional organization. This technology needs to be implemented in 14 key locations in Sudan. Training and skills development of state staff and local communities for the operation and maintenance of the automatic loggers is very important for the technology's sustainability. Automatic water logger was applied in Sudan in the mid-1990s, yet, this technology no longer exists due to technical reasons. Development of flood forecasting systems for Sudan is an important measure that should build upon existing forecasting systems and capacity. Key elements of flood forecasting and warning systems include: (1) data acquisition networks and data transmission (2) data processing and archiving (3) operational forecast modeling systems and (4) flood warning, dissemination and communications. With respect to flood warnings, effective delivery of relevant information in a form readily understandable by and useful to intended users, from government agencies to floodplain dwellers, is essential. One of the main barriers that disfavor the adoption of the technology are its high costs compared with normal gauges and the fact that the technology is sensitive and easy to be broken. Therefore, special care should be taken to its location.

Figure 7: Radar Sensor

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Figure 8: Ceramic pressure cell

2.3.2 Preliminary Targets for Automatic Water Level Technology

The preliminary targets for the Automatic Water Level technology are all the population inhabiting land on the River Nile banks and its tributaries. This mainly covers the White Nile, Blue Nile, Sinnar, Gezira, Khartoum, River Nile and Northern states. These areas represent the bulk of Sudan's population.

2.3.3 Identification of Barriers for Automatic Water Level Technology

The high cost of Automatic Water Level devices, installation cost and required training and sustainable follow up expenses stand as financial and main barrier for the technology application and distribution.
The financial and economic barriers are not the lone main obstacles of this technology. There are a number of barriers impeding the implementation of the Automatic Water Level technology and can be summarized as follows:

- Human skill barriers: needs of continuous maintenance, scarcity of technical know-how, cultural and social unsustainable tranquility
- Technical barriers: Ease of logger damage, lack of skilled person to operate and maintain the system
- Infrastructure barriers: like the lack of proper wireless network
- Awareness barrier: Gap of information, research and development

2.3.3.1 Economic and Financial Barriers for Automatic Water Level

Measures that facilitate adaptation of Early Warning System Technology are:

- Government and non-governmental entities intervention and contribution
- Private sector social contribution
- Continuous annual maintenance should be adopted by qualifying technical experts and disperse know-how at all relevant levels
- Supply a unit with skilled persons to handle operating and maintenance of devices
- Improve wireless networks
- Bridge the current information and development gap that contributes to information and awareness barriers
- Adopt capacity building programs
- Install an emergency control unit to facilitate distillation of information on time

The cost – benefit analysis for facilitated Early Warning System Technology adoptions consist of capital cost of early warning system technology which are included in Table 10:

- Devices and its accessories cost = 220,000 USD
- Installation costs 10 per cent = 22,000 USD
- Training costs and capacity building programs (10 per cent) = 22,000 USD

Table 10 denotes the capital & operating costs of adaptation technology

Item	Cost in $
Devices and accessory equipment	220,000
Installation costs 10%	22,000
Training & capacity building	22,000
Operating costs 35% of capital costs	77,241
Maintenance costs 3% of capital costs	6,621
Total adaptation costs	**347,862**

The annual operating costs include:

- Labor and administration = 77,241USD
- Maintenance 3 per cent 6,621USD

Table (C), Appendix I denotes the annual costs saved by adapting the Automatic Water Level technology. The costs offset by this technology are destruction of infrastructures, human properties, animals and crops all of which annually is approximated on average at 1,000,000, USD and the effect of adaptation starts at 50 per cent in the first year of installation and is expected to increase by 25 per cent from the second year forth, until it reaches the maximum costs savings of 90 per cent in the fourth. This is calculated with an error rate of 10per cent due to low levels of awareness in rural areas.

Benefits of adoption of Early Warning System Technology are:

- Such technologies can be used for warning authorities and society about the imminent natural disasters as heavy rains, floods and tornado.
- Evasion of such disasters is economically considered as returns by saving costs of property damage, animal and crops losses.
- Enable the agricultural authorities to determine the crops that fit the rainfall rates and areas, saving money and efforts by facilitating optimum utilization of resources.

The financial analysis is shown in table 11.

Table 11: Net present value of adaptation warning system technology

	0	1	2	3	4	5	6	7	8	9	10
Initial investment	(264,000)										
Annual returns*		500,000	750,000	900,000	900,000	900,000	900,000	900,000	900,000	900,000	900,000
Annual operating costs		**83,862**	**110,907**	**127,544**	**146,675**	**168,676**	**193,978**	**223,075**	**256,536**	**295,016**	**339,269**
Annual net cash flows		**416,138**	**639,093**	**772,456**	**753,325**	**731,324**	**706,022**	**676,925**	**643,464**	**604,984**	**560,731**
Present value	-264,000	**361,859**	**483,246**	**507,903**	**430,716**	**363,597**	**305,233**	**254,481**	**210,350**	**171,974**	**138,604**
NPV @15	+ 3,227,963										
Profitability index(PI)	10.9										

2.3.3.2 Non-financial Barriers for Automatic Water Level

- **Institutions and policy:**

In Sudan, apart from the contributions of private sector and NGOs, different institutional bodies such as governmental ministries and academic institutions are working with water. Although they deal with these issues in different ways, their mandate and responsibilities are quite similar with certain overlaps and interaction in activities and duties. In spite of all the involvement of different institutions and stakeholders the water resources sector suffers from lack of institutional cooperation and data sharing. One of the reasons is that several legal and administrative regulations prohibit data transfer and data exchange across different governmental agencies. This regulatory barrier leads to institutional barriers for both the rain water harvesting (*Haffirs*) and the seasonal forecasting and early warning (Automatic Water Level) technologies. It also creates a non-collaborative atmosphere among the different institutions. In addition, it destroys communication and data integration across institutions (whether they are governmental agencies, private or academic institutions).

- **Capacity building and public awareness:**

Sudan has limited technical capacity for managing and maintaining Automatic Water Level. The country also lacks skillful human resources for operation and maintenance. Technological skills, human resource development and capacity building problems and gaps have to be tackled. Technically, most of the governmental agencies and research institutions in Sudan have not enough skills and experience to implement Automatic Water Level technologies confidently and effectively. As a result, this technology requires regular and continuous consultations.

- **Technical barriers:**

Technical barriers to implement Automatic Water Level include the sensitivity of the technologies. Hence they have to be secured inside a cage or concrete room to avoid exposure to damage. In addition, Installation, operation and maintenance require high technical skilled personnel. Siltation can technically affect the proper work for some logger types. In this case, pressure types have to be used. For real time transfer of data, automatic loggers need high standard wireless network. The main economic barriers have appeared to be lack of funding for the initial project investment, maintenance requirement and program sustainability. Other barriers are the lack of know-how in maintenance and installation of the Automatic Water Level network and the insufficiency of an essential database management. Hence, training and capacity building components are needed.

2.3.4 Identified Measures for Automatic Water Level

Best water resource management can be achieved by using modern techniques like Automatic Water Level for adequate monitoring and observation of both water quantities and qualities. Adoption of these technologies will assist in reduction or avoidance of the negative impacts of climate change from floods and droughts.

2.3.4.1 Economic and Financial Measures for Automatic Water Level

In order to replace the traditional monitoring system by modern technique, e.g. Automatic Water Level in fourteen river gauge stations in Sudan along the River Nile and its tributaries, the estimated cost has been found to be about 56, 000 USD. These costs can be attained by using funds allocated to the pilot station projects. Hence, the benefit revenue from these pilot stations could be allocated to the annual cost of operation and maintenance. Consequently, it would be easy to

convince the policy makers to provide more funds from other donors to support the technology implementation and maintenance.

2.3.4.2 Non-financial Measures for Automatic Water Level

In order to overcome the identified institutional barriers and promote sustainable development, it is recommended to adopt integrated water resource management in water resources planning and management across all water departments in Sudan.

However, this requires collaborative cooperation with international experts and professionals in these technologies to assist in identifying the best measures and practices. Eventually, the water resources sector would directly gain valuable experiences in supervision, monitoring, management and operational skills. With this approach the institutional capacity will be increased in the whole country in general, and in the water sector in particular. As mentioned previously, lack of skilled personnel is the major concern in adopting Automatic Water Level technology in Sudan. To overcome this problem comprehensive training in installation, operation and maintenance and database management is essential. In remote areas much concern should be taken to secure and prevent the expected damage or lost sensor by providing the automatic loggers with steel cage or concrete housing. Furthermore, it is recommended to look for affordable spare parts in the local market which can replace the more expensive ones. This will conserve the collected water resources data and maintain the sustainability of the system. It is will also be beneficial to use the most reliable wireless network for real time data transfer.

Lack of knowledge, experience, and human resources remain major capacity barriers to Sudan's water resources adaptation technologies. Continuous human resources development via series of training courses could work as a suitable measure. Additionally, awareness sessions for the target groups highlighting importance of the technology are much needed. Regarding the two water sector prioritized technologies the Government should develop an adequate policy to provide the necessary support needed for the establishment and management of an integrated water resource management system in order to monitor patterns of climate change in the country.

2.4 Additional Barriers and Measures in the Water Sector

The seasonal forecasting and early warning system (Automatic Water Level) has a wide international market but it should be ordered and implemented by the government of Sudan, in particular Ministry of Water Resources and Electricity. The Implementation of *haffirs* is usually done by a national contractor and sub-contractor through public tender; the majority of bidding contractors are government owned but some are private.

The interviews with various stakeholders, experts and decision makers, for both water harvesting and seasonal forecasting & early warning system technologies have revealed interesting findings for the two technologies. They have identified relevant capacity, technology and economic barriers that obstruct technology transfer and diffusion of the two technologies. Appendix I shows the problem trees and proposed measures for both technologies. The stakeholder groups have also identified the technologies output services as public and non-market goods which has no market chain and dealers.

2.5 Linkages of the Barriers Identified in the Water Resource Sector

The interviews with various stakeholders and decision makers and experts in water harvesting and seasonal forecasting and early warning system identified capacity, technology, and economic barriers to the technology transfer and diffusion of the two technologies. These are shown in the

problem and measure trees in appendix I. The seasonal forecasting and early warning system has a wide international market but it should be ordered and implemented by the government of Sudan (Ministry of Water Resources and electricity).

Lack of knowledge, experience, and human resources remain major capacity barriers to Sudan's water resource adaptation technologies. Although a few governmental agencies and research institutes in Sudan have experience in design, implementation and operation, of *haffirs* technologies, the majority of institutes lack theses capacities. As a result, most of the sectors may not have enough skills and experience to implement this technology confidently and effectively. Therefore, regular consultation and exchanges of knowledge and experience are required. In addition, the amount of trained experts capable of regular maintenance is very limited and may lead to structural collapse and decreased water storages.

2.6 Enabling Framework for Overcoming the Barriers in Water Resources Sector

In Sudan different institutional bodies including governmental ministries and academic institutes are working with the water sector and are dealing with these issues in different ways, though their mandates and responsibilities are quite similar resulting in certain overlap and interaction in activities and duties; beside the contributions of the private sector and NGO's. In spite of all the different stakeholders and institutes, the Water Resources sector suffers from lack of institutional arrangements and data sharing; hence several legal and administrative conditions and protocols prohibit data transfer and data exchange across different governmental agencies. This regulatory barrier leads to institutional barriers for both the rain water harvesting (*haffirs*) and the seasonal forecasting and early warning (Automatic Water Level) technologies because the regulatory barrier creates a non-collaborative atmosphere among the different institutions. This destroys communication and data integration across different institutions. In order to overcome this barrier it is recommended to adopt integrated water resources management in water resource planning and management across all water departments in Sudan to promote sustainable development. Also, cooperation with international experts and professionals in these technologies to assist identifying the best measure and practices is recommended because the water resources sector can directly gain valuable management and operational experience and supervision, which will increase the institutional capacity of the country. Furthermore, the government should develop a policy providing the adequate support needed for the establishment and the management of an integrated water resources management concerning the two technologies and monitoring the climate change in the country. Technically, Sudan has limited technical capacities for managing and maintaining *haffirs* technology and Automatic Water Level. In addition, the country lacks skillful human resources for operation and maintenance of the technologies. Therefore continuous human resource development, e.g. in the form of a series of training courses and awareness raising programs about the importance of the technology are much needed. Table 12 shows the enabling environment for water sector.

Table 12: Enabling environment for water sector

Market linkage
- No technological transfer network - High technology transfer fees, while old technologies are cheaper and more available - Lack of consideration for externalities such as environment or social factors in calculating technology transfer
Enabling factors
- Week incentive policies for deployment and diffusion of new technology - Lack or rules, standard and implementation - Complicated appraisal and approval procedures - Project location are usually poor urban areas or hard-oil rural areas - Lack of incentives
Support actions
- Lack of support for research and development - Lack of information - Limited project management capacity - Limited local capacity to fill the expert gaps - Required financial mechanism compatible with the new technology

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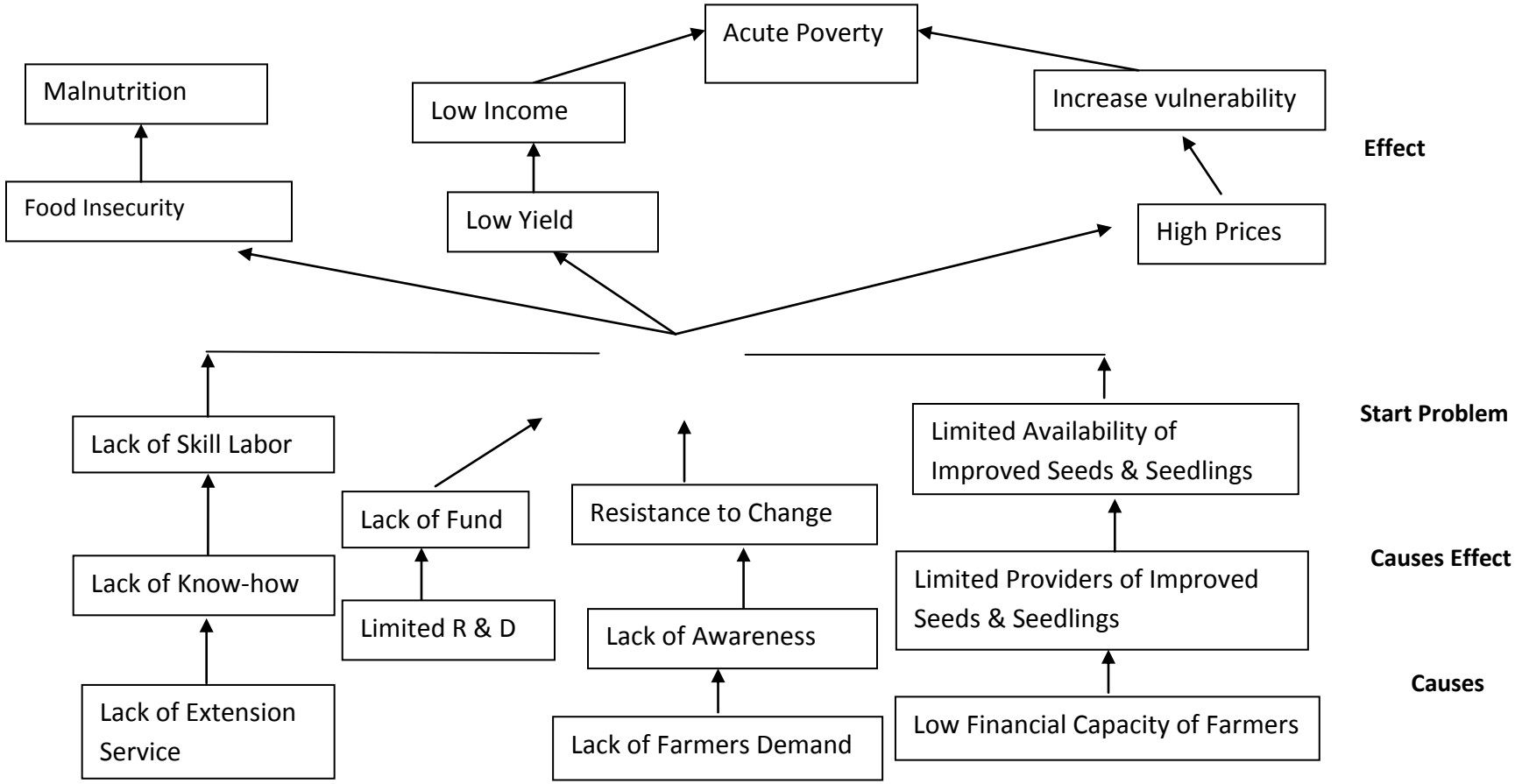
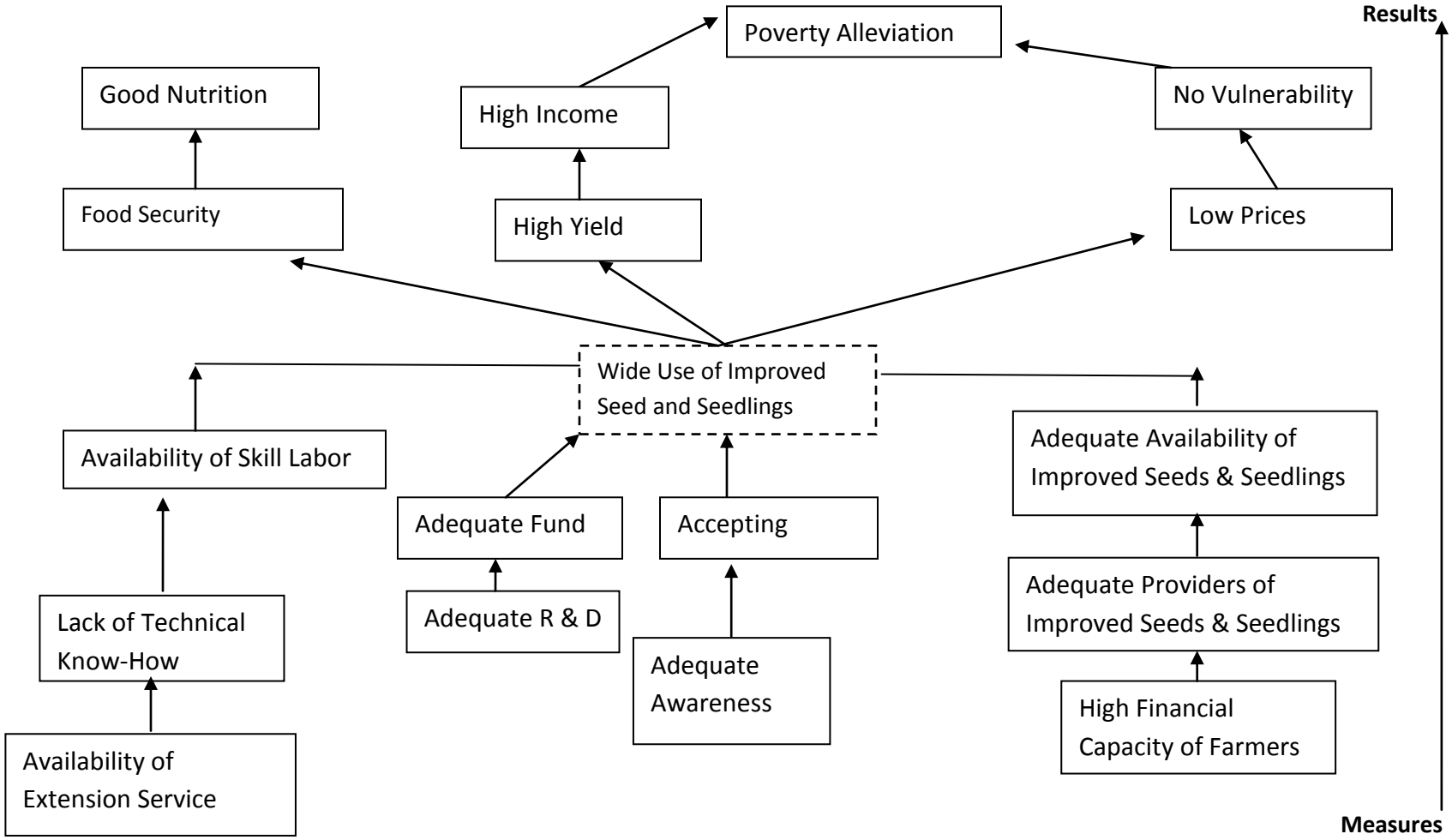
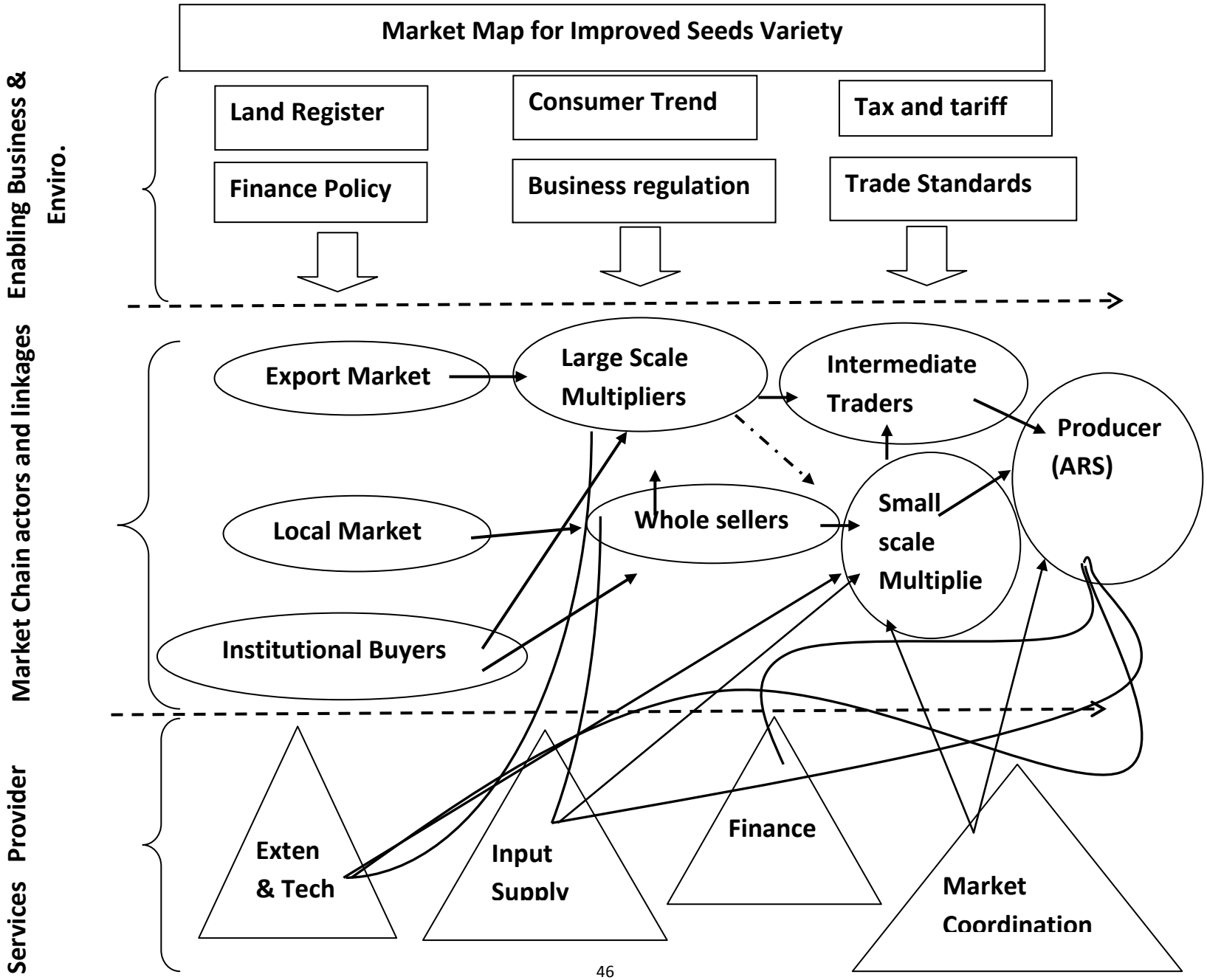
Annex I: Market Maps and Problem Trees
Problem Tree for Improved Crop Varieties Technology
Agriculture Sector



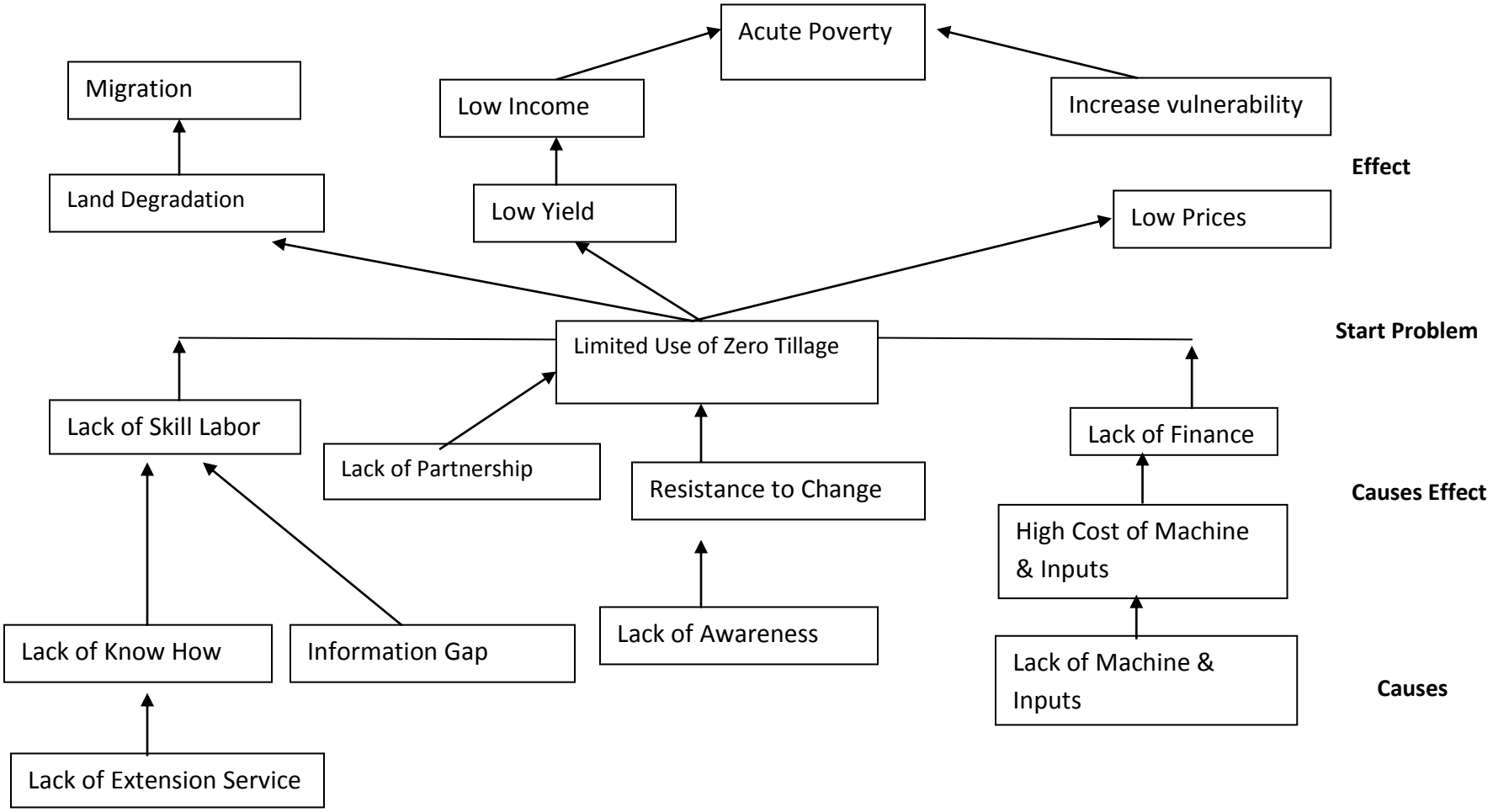
Measures to Overcome Barriers for Improved Crop Varieties Technology
Agriculture Sector




Market Map for Improved Seeds Variety
Enabling Business & Enviro.
Land Register
Consumer Trend
Tax and tariff
Finance Policy
Business regulation
Trade Standards
Market Chain actors and linkages
Export Market
Large Scale Multipliers
Intermediate Traders
Producer (ARS)
Local Market
Whole sellers
Small scale Multiplie
Institutional Buyers
Services Provider
Exten & Tech
Input Supply
Finance
Market Coordination

Problem tree for Zero Tillage Technology

Agriculture Sector



Measures to Overcome Barriers for Zero Tillage

Agriculture Sector

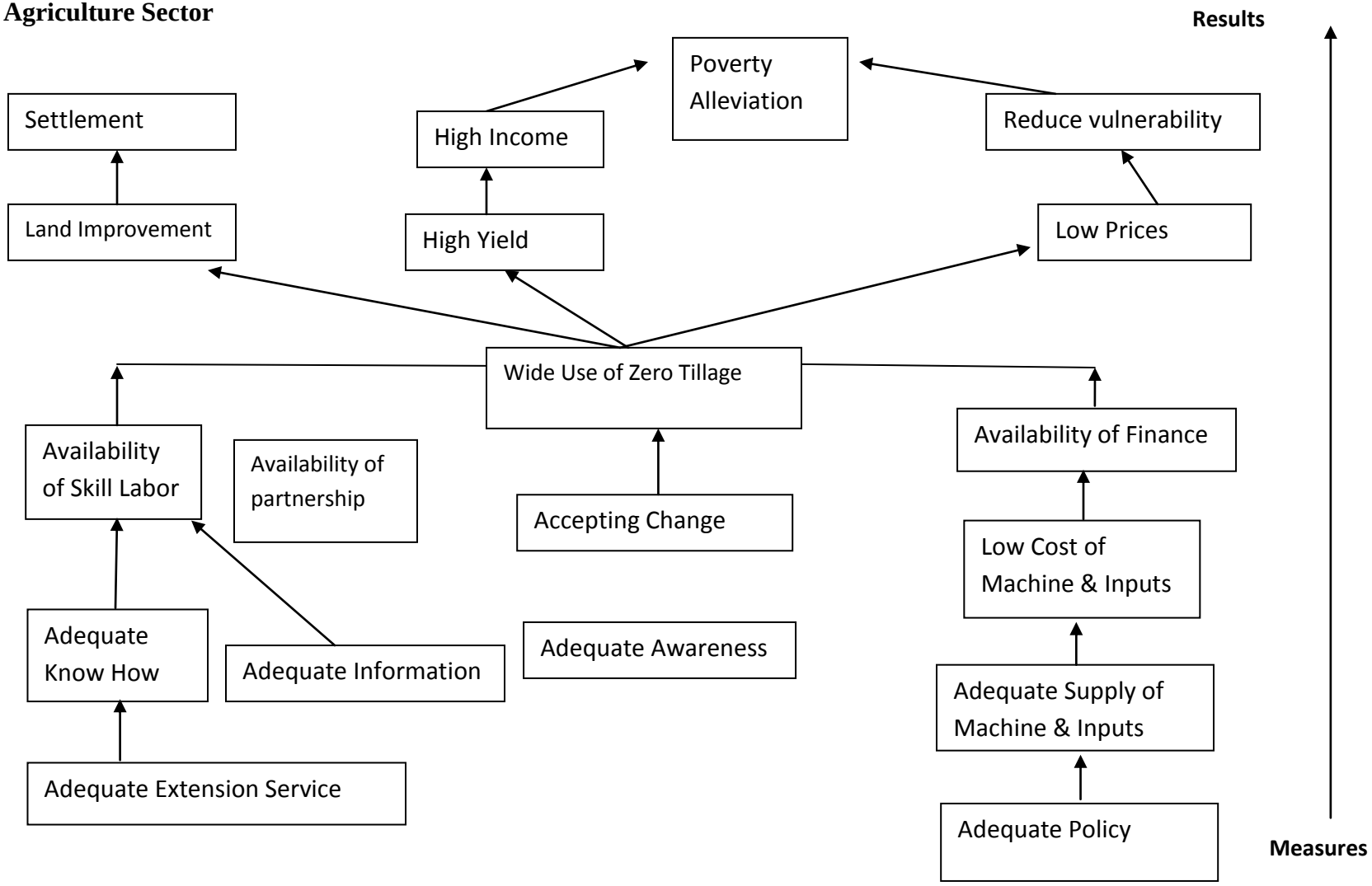


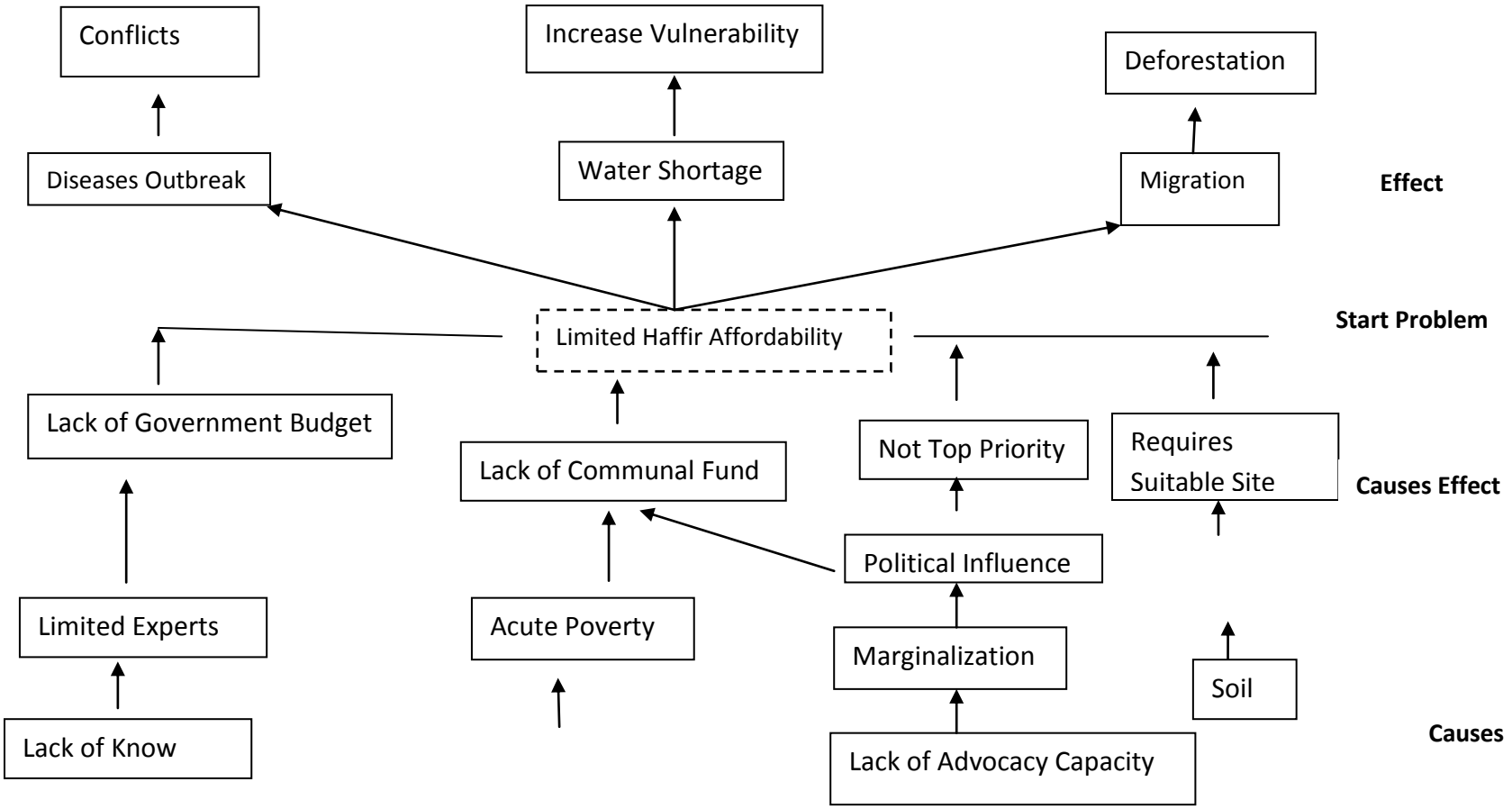
Table (A) Capital and operating costs and effect of Zero Tillage adaptation technology

Capital initial costs of adaptation											
Cost item	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Cooperative society formation & registering fees	3000	0	0	0	0	0	0	0	0	0	0
Tractor & accessory equipment	31,600	0	0	0	0	0	0	0	0	0	0
Pilot farm	64	0	0	0	0	0	0	0	0	0	0
Extension services $1/ fed	3,866	0	0	0	0	0	0	0	0	0	0
Sub- total of capital	38,520		0	0	0	0	0	0	0	0	0
Operating costs											
Production costs	64	64	85	98	112	129	148	171	196	226	260
Management	10	10	11	11	12	12	13	13	14	14	14
Maintenance 3%	2	3	3	3	4	4	5	6	7	8	8
Lubrication 1%	1	1	1	1	1	1	2	2	2	3	3
Finance cost-interest	5	5	5	5	5	-	-	-	-	-	-
Sub- total operating costs	82	104	118	132	151	165	191	217	249	285	285
Total adaptation costs	38,548	2,101	118	132	151	165	191	217	249	285	285

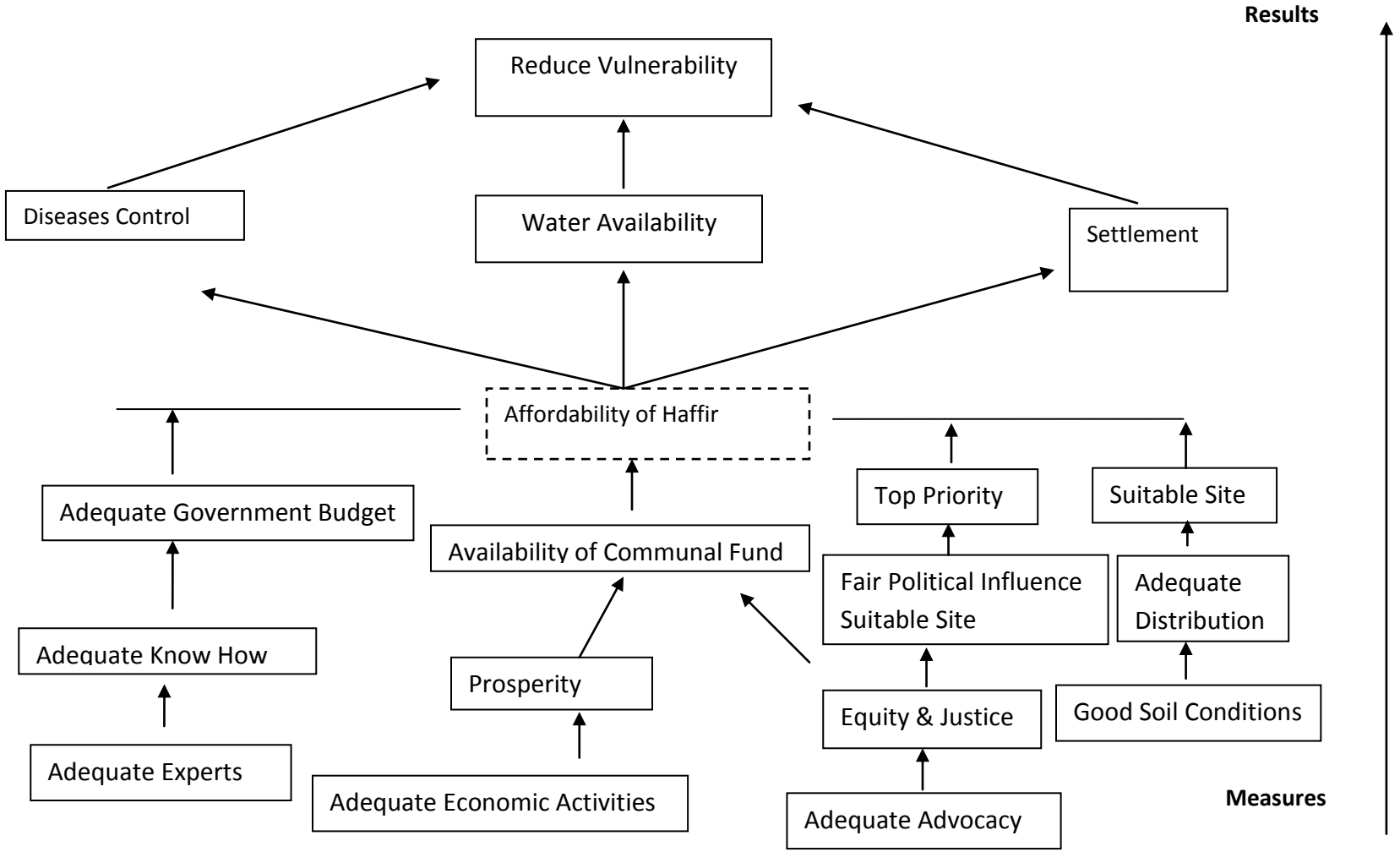
Table (B): Returns of Haffirs technology adaptation

0	1	2	3	4	5	6	7	8	9	10
Annual returns	38,793	51,304	58,999	67,849	78,027	89,731	103,190	118,669	136,469	156,940

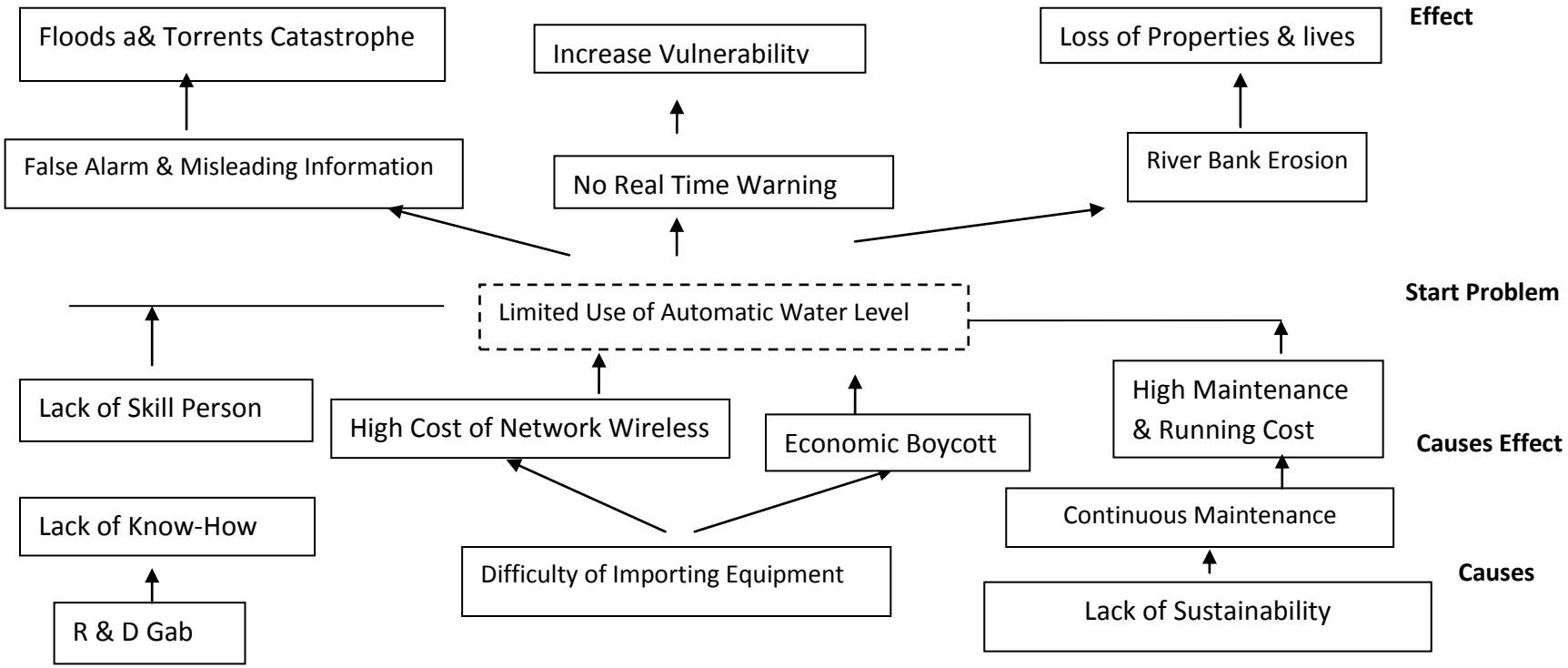
Problem Tree for Water Harvesting (Haffir Technology)
Resources Sector



Measures to Overcome Barriers for Haffirs Technology
Water Resources Sector



Problem Tree for Automatic Water Level Technology
Water Resources Sector



Measures to Overcome Barriers for Automatic Water Level Technology
Water Resources Sector

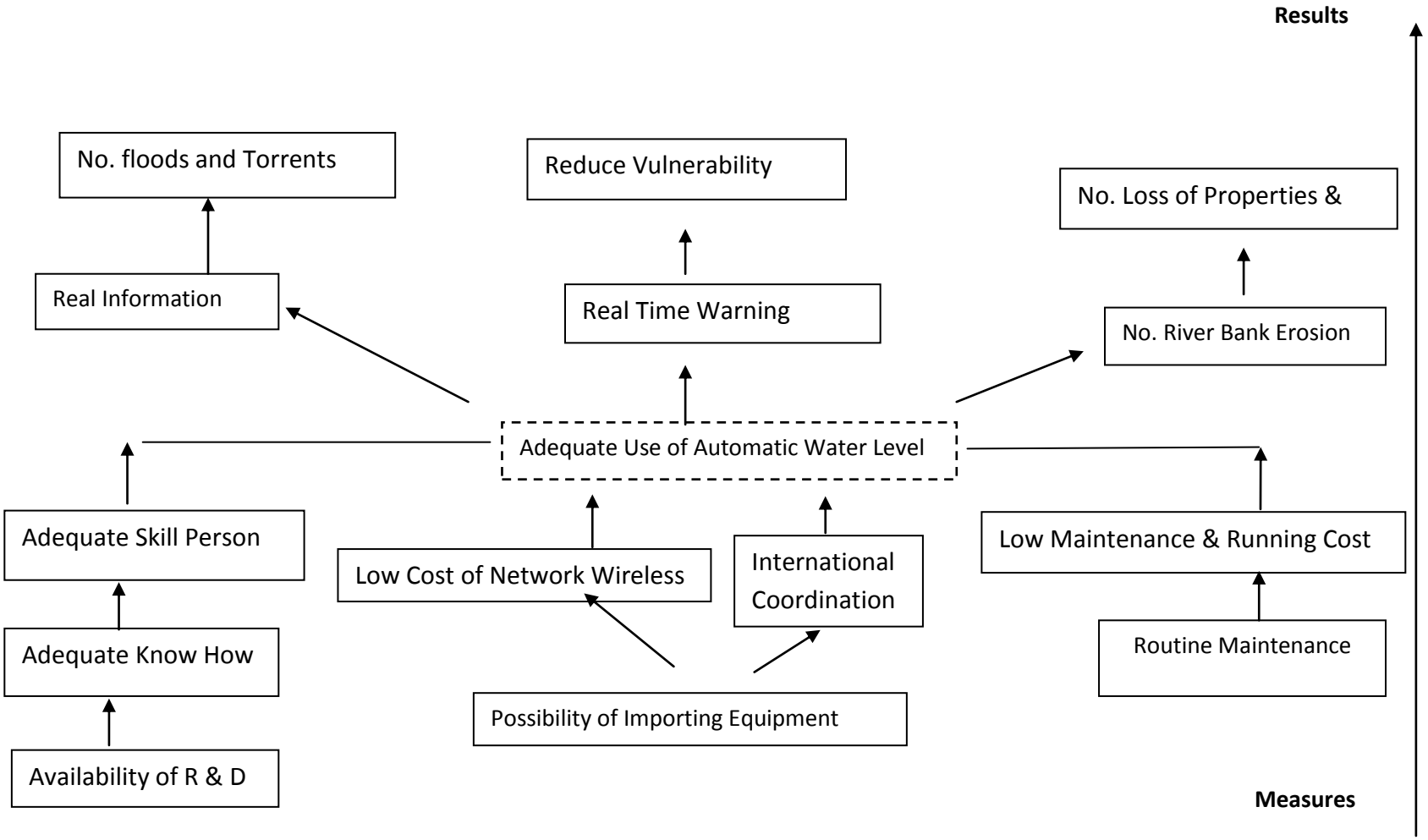


Table (C): The annual costs saved by adaptation the Automatic Water Level Technology

0	1	2	3	4	5	6	7	8	9	10
Annual returns*	**500,000**	**750,000**	**900,000**	**900,000**	**900,000**	**900,000**	**900,000**	**900,000**	**900,000**	**900,000**
Annual operating costs	**83,862**	**110,907**	**127,544**	**146,675**	**168,676**	**193,978**	**223,075**	**256,536**	**295,016**	**339,269**
Annual net cash flows	**416,138**	**666,138**	**816,138**	**816,138**	**816,138**	**816,138**	**816,138**	**816,138**	**816,138**	**816,138**

Annex II. List of Stakeholders Involved and their Contacts
List of Stakeholders Participating in the Inception and the Second Workshop

Name	Institute	Position	Approach of consultation
Igbal Salah Mohamed Ali	Ministry of Water Resources	Researcher	meeting discussion
Widad Motwakil Saadalla	Ministry of Water Resources	Researcher	meeting discussion
Taghrid Abdelrahim	Ministry of Water Resources	Staff member	meeting discussion
Mohamed Yousif Mohamed	Institute for Water Harvesting Research	Lecturer	meeting discussion
Abd Elrahman Saghyroon Elzein	Dams Implementation Unit/ Water Harvesting Department	Director	interview
Tagwa Ahmed Elhabo	Ministry of water Resources/ Water Harvesting Unit	Staff member	interview
Ibrahim Salih Adam	Ministry of water Resources	Head of Technical organ of Water Resources	interview
Ahmed Eltayeb Ahmed Adam	Ministry of Water Resources/ Nile Water Directorate	Director	interview
Issam Aldin Ibrahim Abdal	Ministry of Agriculutre	Staff member	

Annex III: Policy Fact Sheets

Agriculture Policy Fact Sheet

Minimum requirements	
Recommended/ good to have	
POLICY: Name of Policy	Agricultural Revival "The Green Mobilization": the Council of Ministers Resolution No. 173, 2007 for the formation of the High Committee (The high committee under the chairmanship of the Vice President) for the Study of the Current Situation in the Agricultural Sector and the Proposal of Appropriate Visions for its Future Development.
Name of field:	Agricultural Revival (The Green Mobilization)
Date Effective:	April,2008
Date Announced:	2008
Date Promulgated:	2008-2009
Date Ended:	Continuing
Unit:	High Council for Agricultural Revival
Country:	Sudan
Year:	2008

Policy Status:	In force
Agency:	Government and other national institutions including private sectors and farming communities
Funding:	Government- Commercial Banks- Foreign Contribution
Further Information:	25 Year Agricultural Development Strategy (ADS, 2004-2027)
Enforcement:	The programme included a supervision and follow up mechanism chaired by the Vise President, in addition to a High Council for Agricultural Revival, and a General Secretariat responsible for mobilizing and following up revival programmes and projects including the commodity councils.
Penalty:	
Related Policies:	Creating the environment conducive to sustainable development of agricultural productivity and production through the implementation of conductive macro and sectoral policies.
Policy Superseded by:	-
Policy Supersedes:	-

Stated Objective:	The strategic objective is to increase productivity and efficiency at the production and processing stages, Realization of food security, Reducing poverty, Development and protection of natural resources to ensure its renewal and sustainability.
Evaluation:	Follow up mechanism chaired by the Vise President, in addition to a High Council for Agricultural Revival, and a General Secretariat responsible for mobilizing and following up revival programmes and projects
Policy Type:	Economic, financial and finance policies, research policies, technology transfer and extension policies and land use policies (refer to attached tables below).
Policy Target:	Private sector, agricultural support services, farming communities Agricultural production systems(irrigated, mechanized and traditional rain-fed)
URL:	http//www.MoAF.sd
Legal References:	Country 25-Years Agriculture and Articulate a Future Vision and, Action Plan for Agricultural Revival, Republic of Sudan, Council of Ministers, General Secretariat, April 2008.

Description:	Recently, the Sudan has taken a new and strategic direction to support agriculture. This new direction is manifested in the declaration of "The Green Mobilization" and the preparation of the Five-Year Strategic Plan (Agricultural Revival). The executive programme for Agricultural Revival has defined the macro and sectoral policies for creating an appropriate atmosphere for achieving agricultural and agricultural-led industrialization. The programme defined the infrastructure conducive for agricultural development, focused on the development of the supporting services and the protection and development of natural resources .The total cost of this programme is estimated at 10.1 billion SDG (Sudanese Pounds) during 2008 – 2011. This includes governmental contribution, foreign, bank-lending and self-financing in addition to the agricultural season's subsidies. The programme is expected to achieve tangible results, most significant of which is the development of the farming systems and introducing participatory methods of natural resources management, ensuring sustainable use of these resources and reduce conflicts over them.

Policy Fact Sheets for Water Sector:

Policy name:	Country Strategy on Integrated Water Resources Management
Date effective	In draft
Date announced	In draft since 2007
Date promulgated	Still in darft
Unit	CC
Country	
Year	Still draft
Policy status	
Agency	Ministry of Water Resources and electricity
Funding	
Further information	The policy document, in draft since 2007, is mainly related to very limited consultation at all levels along with some conservations on the content of the policy
Enforcement	
Penalties	Policy is giving principle for water resources management; penalties were included in 1995 the Water Resources Act, which is not active
Related policies	Environmental Conservation Act (2001): provides general principles and guidelines to be considered in implementing any development project. Protection of natural resources and endorsement of the principle of "polluter pays"

	The draft National Water Supply and Sanitation Policy (2009). Recently the Public Water Corporation, supported by UNICEF, has drafted a national Water Supply and Sanitation Policy. The thrust of the policy is to ensure equitable and sustainable utilization and provision of safe water and sanitation with view of achieving the MDGs.
Policy supersedes	
Stated objective	To adapt with climate change and ensure rationale use of water resources
Evaluation	Not yet
Policy type	No list is provided classifying policies
Policy target	No list is provided
URL	
Legal reference	The policy is still in draft
Description	To lay the foundation for a rational and efficient framework to sustain the water needs of national economic development, poverty alleviation, peace, environmental protection and social well-being of the people through sustainable water resources management. As per information provided limited consultation was one of the key drawbacks of the this policy and consequently limited stakeholders

Policy fact sheets for Water Sector:

Policy name:	Water, Sanitation and Hygiene (WASH) Policy
Date effective	In draft since 2009
Date announced	In draft since December 2009
Date promulgated	Still in drft
Unit	CC
Country	
Year	Still in draft
Policy status	Final draft
Agency	Ministry of Water Resources and electricity, Public Water Corporations (PWC)
Funding	
Further informations	The policy document is in draft since 2009, wide consultation conducted at different levels and the policy was highly recommended to be approved
Enforcement	
Penalties	No penalties were included only guidelines on how to manage water supply.
Related policies	
Policy supersedes	
Stated objective	This policy aims to achieve the strategic objectives of quarter of the century 2007-2031, that targeted increasing rates of access to safe water in rural areas by 20 liters per capita per day, and up to 90 liters per capita per day in cities In addition, it aims at increasing rates of sewerage services to 67 per

	cent of the population of Sudan in rural and urban areas by the end of in 2015 to achieve the objectives of the third Millennium Development Goal. The frequent increase in the levels of services, safe water to 50 liters per capita per day in rural areas and 150 liters per capita per day in urban areas, in addition to coverage of, all schools and public health facilities to achieve the goals by the end of the 2031
Evaluation	Not yet
Policy type	No list is provided classifying policies
Policy target	No list is provided
URL	
Legal reference	The policy is still in draft
Description	The objectives of the policy to improve access of water and adequate sanitation in a sustainable way. This can improve the health and preservation of the environment and the living conditions of the population as well as to contribute to the positive growth of the economy in the country and the best use of resources. The policy widely accepted but it is still in draft due to continuous change in government structures and rapid turnover of key ministers and senior governmental officials. Key stakeholders are SWC, NGOs, private sector, communities and UN agencies