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Assessment of Major Environmental Constraints of Riverside Cultivation in Omdurman (Sudan) by Use of Local Knowledge

Elsir A. Salih[a*], Neama A. Elias[b]

[a,b]*Department of Biology, Faculty of Education, Alzaeim Alazhari University, Khartoum, Sudan*
[a]*Email: elsir.adam@yahoo.com*
[b]*Email: anog52525@gmail.com*

Abstract

The use of local knowledge, particularly in dealing with environmental issues, has gained increasing attention in recent decades because of the growing scientific consensus on the value and credibility of this knowledge in environmental management and strategic planning. The aim of this study was to use farmer's knowledge to identify the major environmental constraints that impede the indigenous riverside farming in Omdurman and to assess to what extent such knowledge is applied to mitigate the severity of those constraints. Structured interviews were performed with 25 farmers in the study area. The results showed that local farmers have good knowledge about the predominant environmental constraints that hinder their crop production, and this knowledge has helped them to alleviate these constraints, but despite the importance of this knowledge in making this type of agricultural practice sustainable for several decades, it has not been incorporated effectively in management and strategic planning. The results also showed a growing tendency towards modern technology, such as chemical fertilizers and pesticides, but this trend has not been accompanied by a proper scientific guidance and if it continues with the same manner it will inevitably result in many health and environmental risks in the near future. The study concludes by recommending that indigenous knowledge and practices are useful, must be integrated with contemporary research agenda, also the adoption of modern technology must be accompanied by an appropriate scientific enlightenment with its negative consequences.

. ***Keywords:*** Local knowledge; environmental constraints; modern technology; agriculture in Omdurman.

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* Corresponding author.

1. Introduction

Since its emergence as a basic mean of subsistence, Agriculture has been associating with many environmental factors that constrain crop production. A wide range of naturally occurring biotic and abiotic constraints, including poor soils, water scarcity, crop pests/diseases/weeds, and unsuitable temperatures, are well-known to reduce the productivity of food crops, leading to low efficiencies of input use, suppressed crop output, and ultimately reduced food security; e.g. references [1, 2, 3, 4, 5]. Most of these constraints were reported to be very detrimental for crop productivity and hence threaten the long-term viability of agriculture and agro-ecosystems in many parts of the world particularly sub-Saharan Africa [6, 7, 8, 9, 10, 11, 12].

Local Knowledge Systems (LKS) consist of the knowledge, beliefs, traditions, practices, institutions, and worldviews developed and sustained by indigenous and local communities [13]. Knowledge systems evolve through human interactions among themselves as well as with nature within and without [14]. Indigenous knowledge (IK) has become an interesting topic and a growing field of investigation, both nationally and internationally, with increasing attention being paid to IK by academia and institutions [15, 16]. In both social and biological sciences a consensus has emerged about the value and credibility of local knowledge concerning environmental issues which suggests an increased use of local information as bases for management strategies [17, 18, 19, 20, 21].

In many areas in Africa several environmental constraints were reported to be seriously damaging factors for crops for example weeds in Benin and Ghana [22, 23, 24] Crop pests and disease in Togo, Uganda, Rwanda, Kenya and Tanzania [25], and soil nutrient depletion in sub-Saharan Africa [26]. However, in addition to these predominant traditional constraints, others unfamiliar constraints, such as climate change and erosion of crop genetic resources, have been recently emerging in the literature.

The aim of this study was to use farmer's knowledge to identify the major environmental factors that constrain the indigenous riverside farming in Omdurman and to assess to what extent farmers have benefited from such knowledge in finding solutions to these constraints.

2. Materials and methods

2.1. The study area

This study was conducted in Omdurman which represents one of the three towns that jointly comprise the capital of Sudan, Khartoum city. Omdurman is situated between latitudes 31^o 37' and 32^o 36' N and longitudes 15^o 11' and 16^o 39' E on the western bank of White Nile and River Nile. The area is located within the semiarid zone which is characterized by a hot climate most of the year with an average annual temperature of 29.0 °C and a short rainy season (July-September) with an average annual rain of 125 mm. The area is a plain surface gently sloping towards the White Niles and river Niles, generally elevated between 400 to 380 m above mean sea level (a.m.s.l.). It is characterized by its scanty vegetation that can be increased along seasonal drainage pattern and river banks. A narrow cultivated strip that extends along the western bank of the River Nile, from the confluence of the Blue and White Niles to about 30 km northward, represents the area which has been investigated. It covers an area of about 25 km^2 (= 2500 hectares) and it comprises approximately between 250 and 350 farms with an average area of 6 hectares each (the small farms < 3 ha. were excluded). During autumn season (July-September), the River Nile is highly charged by water beyond its normal capacity, the factor that results in the flood and flow of water from the main stream to the adjacent farmlands. The farmlands remain under inundation until late October. After the receding of the flood, some crops, such as melons, cucumbers, potato etc. are cultivated in the moist soil. The soil is mainly river silt (mainly clay with little sand).

2.2. Data collection

The field work was carried out between March 2016 and February 2017 in the prescribed study area in Omdurman. A quantitative research approach was applied through structured interview which was conducted using face-to-face method. The motive of choosing this approach was to create a more nuanced picture, gain a deeper understanding of the farmers' perceptions and experiences, and obtain comparable and reliable data. However, the main drawback of this approach is that it is formal and less flexible and therefore the interview guide must be well developed and tested before the actual survey. To achieve this pre-field work survey was done and the capability of the scheduled-questions in generating the required information was tested. This method was preferred over individual questionnaire, as farmers are difficult to reach by postal mail and illiteracy among farmers is common in the region. 25 cultivated fields were randomly selected and their owners (farmers) were interviewed. Due to the variation among the fields in areas, which range between 1 and 6 hectares, the selection was directed towards medium to large fields (3-6 ha.) with multi-cropped practice, since these were assumed to provide more information about the environmental constraints compared to the small mono-cropped ones. The questions were focused on the levels of farmer's awareness about the major environmental factors that constrain crop productivity in the area, how farmers utilize these knowledge in mitigating the effects of these constraints, and the tendency of farmers towards modern technology. The questions were presented orally and were replied by way of oral-verbal responses. All the answers were documented and subjected to statistical analysis.

3. Results and discussion

3.1. The major environmental constrains

According to the interview with farmers and as indicated in Fig (1), the major environmental constraints that affect crop production in the study area are: weeds, pests, soil nutrient depletion and soil water depletion. However, weeds and pests, as reported by 100% and 96% of farmers respectively, are considered to be the most outstanding ones compared to soil nutrient depletion and soil water depletion with 40% and 36% respectively. These constraints are in general among the major constraints reported from the other parts of the world, particularly, the tropical regions [9, 10, 11, 12]. However, it is important to notice that soil degradation which is considered as one of the most outstanding constraints of agriculture worldwide [27, 28] was not regarded by farmers as a serious problem. This may be attributed to the nature of this riverside cultivation which leaves soil, for most of the year, either under cultivation or under flooding the factor that highly protects the topsoil from being eroded by wind and runoff in addition to that the annual arrival of silt and some organic materials with water currents partially replenishes the soil quality. Beside soil degradation, climate change and erosion of crop genetics diversity, which are recently emerging in literature as important agricultural constraints, were also received very little attention and were not listed among the major constraints. As for climate change farmers talked about some occasional changes in the flooding regime and temperature probably due to the variation in the lengths of the seasons of the year e.g. when they have late autumn or mild winter. According to farmers, this might slightly delay the time of farming or harvesting without clear impact on crop production. On the other hand the main factors that reduce agro-biodiversity are the shift to more-intensive farming systems and the replacement of multiple locally-adapted and genetically diverse crop landraces or varieties with a smaller number of modern varieties [29, 30]. Both of these two factors here have very minor effect because farmers are adhered to their inherited traditional farming system while the shift to modern crop varieties, in spite of the fact that it is getting more attention, was being reported for very few crops such as tomato, onion and alfalfa.

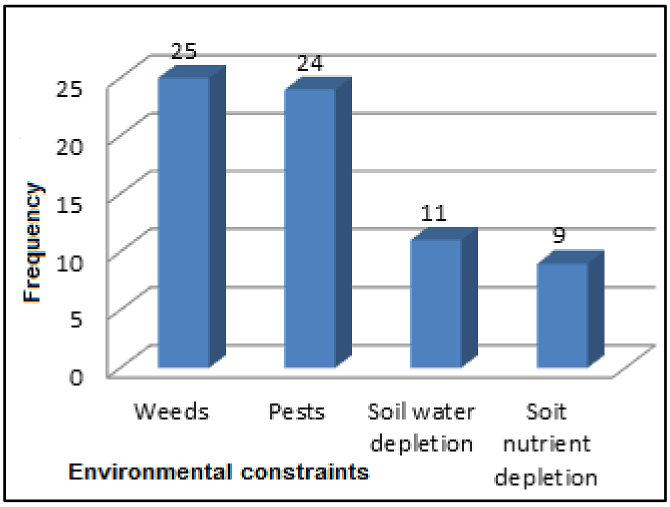

Figure1: Environmental constraints as ranked by farmers.

3.1.1. Weeds

In regard to the major weeds species that spread in the study area; farmers reported 18 weed species, which belong to 10 plant families, as common to abundant in the area (table 1 and figure 2). Most of them (33.3%) belong to the family Poaceae and hence most of them are grasses, 22.2% of them are shrubs that belong to different plant families while the rest (44.4%) are either herbs or small trees. According to farmers, these weed species spread throughout the study area regardless of the crop species that grown. Their spread is highly controlled by the prevailing environmental conditions mainly soil type and soil moisture.

Farmers are very aware of the negative consequences of weeds on their crop production. They believe that weeds affect crop productivity mainly through competing with crop species over water, soil nutrients and space, as well as hosting pests and reducing crop quality when mixed with harvest. According to farmers, weed competition is most serious when the crop is young therefore weeds need to be cleared from a field prior to planting a crop and again during the growing season for optimal yields to be achieved.

Table 1: List of the most occurred weed species in the study area as reported by farmers.

Scientific Name	Common Name	Growth Habit	Family	Occurrence
Alpinia officinarum	Lesser galangal	Perennial herb	Zingiberaceae	Frequent
Amaranthus eruciformis	Fringed amaranth	Shrub	Amaranthaceae	Common
Ambrosia maritima	Damassia	Herb	Asteraceae	Common
Anogeissus schimperi	African birch	Tree	Combretaceae	Frequent
Brachiaria eruciformis	Sweet signal grass	Grass	Poaceae	Common
Cynodon dactylon	Couch grass	Grass	Poaceae	Abundant
Cyperus rotundus	Nut grass	Grass	Poaceae	Abundant
Echinops spinosissimus	Viscous globe-thistle	Perennial herb	Asteraceae	Frequent
Eragrostis cilianensis	Stink grass	Grass	Poaceae	Common
Fagonia cretica	Fagon bush	Shrub	Zygophyllaceae	Common
Grewia flavescens Juss	Donkey-berry	Shrub	Malvaceae	Frequent
Hibiscus trionum	Bladder hibiscus	Annual herb	Malvaceae	Common
Ochthochloa compressa	Hamraya	Grass	Poaceae	Common
Salix alba	White willow	Tree	Salicaceae	Frequent
Sporobolus sp.	Smut grass	Grass	Poaceae	Common
Tamarix arabica	Tamarisk	Shrub or Tree	Tamaricaceae	Frequent
Trianthema pentandra	African purslane	Grass	Aizoaceae	Common
Tribulus Terrestris	Bindii	Annual herb	Zygophyllaceae	Common

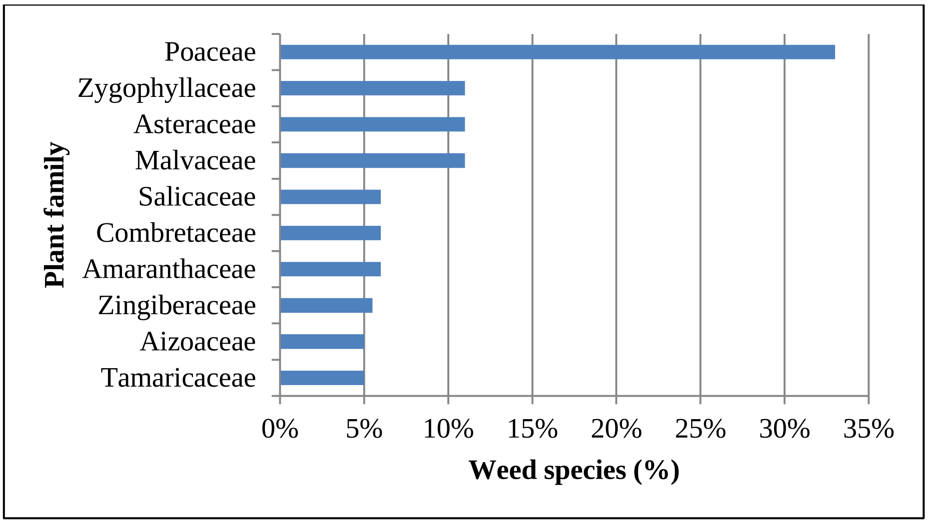

Figure 2: Distribution of the major weed species among plant families

There is agreement among farmers that under unweeded conditions, crop losses may be more than 50% and may even reach 100% depending on the crop species. This result is in line with the results of many studies that reported that the detrimental effects of weeds in Africa far exceed the world average. For example, it is estimated that in Africa yield losses due to weeds range from 25% to total crop failure [31, 32, 33, 34]. The majority of farmers in Ghana identified weeding as the main constraint in their farming system, with a major effect on yields [35]. In Benin, investigations carried out in the different agro-ecological zones revealed that weeds are a serious constraint on crop production [36, 23, 24]. Apart from Africa there are many other areas in the world where weeds were reported as major constraint for examples Pakistan [37] and United States of America [44].

To minimize the severity of weeds on their crop production, farmers refuge to several methods of weed control which comprise some traditional methods they used to, such as mowing, and some modern ones such as spraying of chemical herbicides. To decide which method of control to be applied depends on the weed species, particularly, its growth habit and its means of propagation. In this context and according to the respondents the weed species can be categorized into two groups. The first group comprises the species that possess fast means of propagation and hence have high rate of growth to compensate and establish themselves. The species of this group are difficult to control and are represented mainly by the members of Poaceae family, particularly, those which can propagate by vegetative methods such as *Cynodon dactylon* and *Cyprus rotundus.* These two species are considered by local farmers as the most noxious weeds. The former spreads by scaly rhizomes and flat stolon to form a dense resilient turf, while the later spreads quickly by rhizomes and tubers. As indicated in table (2), the members of these fast-propagated species are eradicated by combining both mechanical and chemical methods of control. The second group comprises the species which propagate mainly by sexual mean i.e. seeds such as *Tribulus terrestris* and *Amaranthus eruciformis* and hence are less difficult to control. In this case, mechanical control might be effective.

Farmers mentioned several methods of mechanical control that they often use mostly; hand pulling, mowing and sickling. However, some other methods of mechanical control such as tillage and deep ploughing, which were reported by several studies [38, 39] to be widely used in other parts of the world, are applied here in a very limited scale. Farmers attributed this to the nature of this riverside farming practice, in which agricultural operations should begin immediately after the recede of the flood and at that time the soil is wet and muddy, the factor that makes the application of these two methods practically difficult.

Farmers acknowledged that mechanical control is the most accessible to be used but they believe that mechanical control is not always a solution in itself, and follow-up is often required i.e. it is labour intensive, time consuming and less effective. This factor push farmers to look for another option that is faster and more effective and they found that in chemical herbicides. In total 22 out of the 25 interviewed farmers i.e. 88% use chemical control but (72%) out of that preferred to combine it with mechanical control (figure 2). There is a general consensus among farmers that without chemical herbicides the yield would be reduced to less than half or that may result in a total crop failure. It worth mentioning that herbicides are applied first to weaken the weed species so that they can easily eradicated mechanically afterwards. This finding is in agreement with the findings of several authors [40, 41] who pointed out to the rapid recent surge in herbicide adoption in the

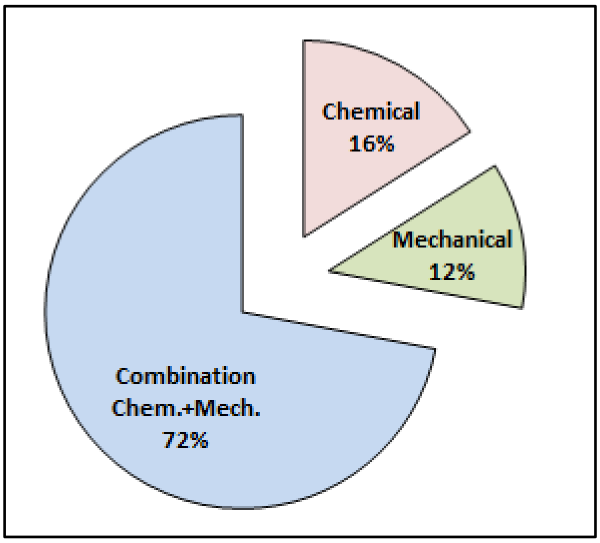

Figure 3: Methods of weed control adopted by farmers

developing world, but it is in contrast with [42] who reported that chemical weed control is not widely practiced in developing countries because of relatively cheap labor, high chemicals prices and lack of technical extension and experience in herbicides application which leads in most cases to the misuse of these chemicals and crop injury, failure of selective herbicides and weed control operation, soil and air pollution and limitation in crop rotation options.

Table 2: Farmers knowledge about the most noxious weeds and the methods of their control

Weed species	Method of propagation	Method of control
Scotch grass	• Mainly by scaly rhizomes and stolon • Seeds	• Mechanical (mowing + digging) • Chemical (herbicides)
Nut grass	• Mainly by rhizomes and tubers	• Mechanical (mowing) • Chemical (herbicides)
Bindii	• Seeds	• Mechanical (Cutting)
The tamarix	• Seeds	• Mechanical Cutting

In their answers to the question of whether the annual inundation of their farms by the water of the river can retard weeds growth. Farmers stated that flooding has two contrasting effects. On one way it suppresses the growth of weeds particularly those species which do not form underground stems for regeneration, and on other it Aggravates the problem by bringing seeds and other weed's fragments that grow and result in fast weeds infestation.

3.1.2. Pests

Pests were the second most important constraints elicited by the local farmers. According to the respondents, agricultural pests, although less destructive to crops than weeds, could cause a significant reduction in yield especially as they include some pests that have been globally classified among the most crop-damaging pests in the world such as white fly (*Aleyrodidae*) and US worm (*Heliothis armigera*) [43, 44].

The interview clearly indicated that farmers are well aware of this problem. Several pest species have been reported by farmers as spreading in the farming area, but only 6 species (see table 3) have been mentioned as being common to abundant and hence have detrimental effects on crop production. Almost all these species, as indicated in table (3) are nonspecialized parasites i.e. each of which affects wide range of host crop plants that belong to different plant families. This parasitic behavior, as mentioned by farmers, makes it difficult for some cultural control methods, such as crop rotation, to succeed because the rotation will not be effective in eradicating the pest as long as it can survive on most of the crops in the rotation cycle. This finding is in agreement with many other studies ([45, 46] which stated that; for crop rotation to control an insect pest well, the insect must spend the period from the end of one crop to the beginning of the next in a stage with low mobility and must have a restricted range of host plants. Not many insect pests fit this pattern.

Farmers agreed that without measuring control the loss in the crop productivity due to pest infestation would be high and may even result in a total failure of some crop species such as spinach, cucumbers or tomato when attack by the white fly. This significant negative impact of pests on agricultural productivity, as reported by famers, has also been confirmed by many scientific studies in many other regions of the world (e.g. [47, 48].

In recent decades, the human population of Khartoum city has dramatically increased due to the exodus from countryside, this in turn has steadily increased the demand for food, and hence for crop products. This has led farmers to seek for more effective and faster ways to increase their agricultural products to meet that demand and to meet their living needs which are also rising. Since access to new lands in this narrow arable strip along the riversides is rather difficult, productivity must be increased per unit area. To achieve this, more agricultural inputs, such as pesticides and fertilizers, must be added. Thus, farmers have begun to reduce their reliance on the traditional low-return control such as physical pest repellents, scarecrows and fumigation, and shift gradually to faster-return chemical control. As shown in table (4) all the respondents, with no exception, use chemical pesticides in spite of the fact that most of the pesticides are expensive and some of them are even out of the normal range of most of the farmers. This growing trend in the use of chemical pesticides has also been reported for many areas in the world particularly in developing countries [49, 50].

It worth mentioning that farmers never referred to the use of biological control, which is recommended by several scientific studies [51, 52] as the most environmentally safe.

With regard to farmers' knowledge of the risks that may arise from the use of chemical pesticides, and as it shown in table (4), it appeared that most of the farmers are well aware that pesticides are harmful to their health (84%) and to the environment (72%), but most of them do not know how pesticides exactly affect the environment, for example most of them do not realize the effect of pesticides on the beneficial soil microorganisms, and that the misuse may results in development of resistant pests. In addition, farmers' level of knowledge of pesticide safety is insufficient. All the interviewed farmers had not received any training or technical support on the judicious use and safe handling. Over 70% of the farmers did not read or follow instructions on pesticide labels, because they were unable to read and understand the meaning of the labels, the labels were written in English (a foreign language to them), and the instructions were too long and complicated. These results are in consistence with several other studies that focused on the use of pesticides in developing countries [53, 54, 55] who reported that the greatest obstacle between herbicide technology and farmers in developing countries is lack of awareness and training.

Table 3: The most occurred pest species in the study area.

Scientific Name	Common Name	Family	Occurrence
Aleyrodidae	Whitefly	Aleyrodidae	Abundant
Camponotus onsobrinus	Sugar ants	Formicidae	Common
Heliothis armigera	Cotton bollworm	Noctuidae	Abundant
Rattus norvegicus	Brown rat	Muridae	Common
Schistocerca gregaria	Desert locust	Acrididae	Common
Tetranychus telarius	Red spider	Tetranychidae	Abundant

Table 4: Farmers' knowledge, attitude and understanding about pesticide (n = 25).

Question	n	(%)
Do you use chemical pesticides for controlling pests?	25	100
Do you think that pesticides affect human health?	21	84
Do you think that pesticides affect the environment?	18	72
Do you receive extension service and training on use of pesticides?	0	0
Do you read, understand and follow pesticide labels?	7	28

3.13. Low soil fertility (nutrients deficiency)

Soil fertility is an important factor to measure the quality of the soil as it indicates the extent to which it can support plant life. Scientifically, soil fertility is measured by the amount of macro and micronutrients, water, pH etc. In the case of this study farmers rely mainly on their experience to rate the level of soil fertility. According to the farmers, Low growth rate, appearance of phenotypic symptoms of diseases and low yield are the main indicators of nutrient deficiency. As indicated in table (5) 36% of the respondents believe that soil fertility is low, 60% of them consider it as moderate while only 4% consider it as high in view of the level of the crop productivity they aspire to obtain. There is a general consensus among farmers that crop productivity varies significantly with and without the application of chemical fertilizers. 24 out of the 25 interviewed farmers (i.e. 96%) said that crop production may reduce by 30-50% without chemical fertilizers and hence they must use fertilizer to increase crop yield. This result is in agreement with [56, 57] who reported that soil fertility depletion on smallholder farms has been cited as the fundamental biophysical root cause responsible for the declining per capita food production in sub-Saharan Africa.

Despite the differences among farmers in rating soil fertility levels, very slight differences were observed in the types of fertilizers they use. All the farmers (96%) who acknowledged the use of fertilizers depend entirely on chemical fertilizers and all of them use urea, while, 27% of them combine urea with other chemical fertilizers. As shown in table (5) the amount of chemical fertilizers used for one growing season ranges in average between 37- 67 kg/hectare but the amount varies according to fertility levels and crop species, for example onion *(Allium cepa)* requires relatively higher amount compared to other crops such as tomato (*Solanum lycopersicum*) and potato (*Solanum tuberosum*). With exception of urea which is applied in soil all the other chemical fertilizers are sprayed directly on the leaves and stems of the crop plants. According to the farmers, these kinds of fertilizers give quick effect on the plant growth but their application requires knowledge e.g. the doses must not exceed certain limits, the spray must be done early in the morning when temperature is suitable and with wind direction.

It is surprising and contrary to what was expected, animal manure was not considered as important fertilizer and it was being mentioned only by 8% of the farmers, and even in these cases farmers said that the benefit is very minor because the number of animals they rear is very few just for helping them to meet their family needs. This is not in line with several studies [58, 59, 60] that reported that animal manure is important input in improving soil fertility and quality.

Table 5: Rating of soil fertility levels and the average amount of fertilizers used per season

Soil fertility level	No. of respondents	(%)	Average amount of fertilizers used (Kg/ha)
High	1	4	None
Moderate	15	60	37.5
Low	6	24	50.0
Very low	3	12	67.0

3.1.4. Soil moisture scarcity

In their answers to the question of whether soil moisture is enough to sustain farming year-round, farmers were different. In general 44% of the farmers mentioned that the depletion of soil moisture is a major constraint for cultivation at least during some months of the year, while, 56% of them consider it as minor or even unimportant. But even among those who suffer from the problem a variation was observed, 36% of them said that they suffer from the shortage of soil moisture in summer as well as in winter season, 55% in summer only and 9% in winter. However, it is important to point out that a link was noticed between the rating of farmers to the issue and the locations of their farm from the main stream of the river, for example, all those who underrated the problem of soil moisture depletion have their farms adjacent to the river while those who feel the severity of the problem are those whose farmlands are distant.

Farmers use different methods to overcome this problem based on the location of their farms from the main course of the river and the length of the dryness. Those whose farms are close to the river, if forced to use water, adopt very traditional methods to deliver water to their lands e.g. by opening channels manually using their hands or simple excavators. Other farmers whose farms are relatively away from the river use pumps to take water through pipes from the river, however, few of them drill wells in their farmlands to get an easy access to water. According to the farmers the high prices of petroleum products, needed to operate the pumps, have been clearly reflected on crop productivity.

4. Conclusion and Recommendation

The study concludes by recommending that the indigenous knowledge of the respondents was good but need to be sustained and improved through continuous training and extension contact with farmers, this knowledge and practices are useful, must be integrated with contemporary research agenda, and that the adoption of modern technology must be accompanied by an appropriate scientific enlightenment with its negative consequences.

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