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GROUND WATER DEVELOPMENT FOR IRRIGATION IN NIGER REPUBLIC: IMPLICATIONS FOR A SUSTAINABLE INCREASE IN AGRICULTURAL PRODUCTION IN A SEMI-ARID ENVIRONMENT

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ABSTRACT

The environmental hazards of drought and desertification constitute serious problems in arid and semi-arid regions of the world where water supply is inadequate. Irrigation is seen as one of the most effective strategies for combating these problems. Irrigation is also considered necessary to increase utilization and productivity of agricultural resources in such areas. It is expected that such increases would not only increase agricultural output, but also farm incomes. In Niger Republic, an irrigation project based on ground water development has been established in the Tarka Valley. This study evaluated the effects of the new technologies of tubewell and pump, being introduced by the Project, on resource use, crop yield and farm incomes. The results indicated that the technologies possess the potential for achieving the desired objectives, but they could create further deterioration of the environment unless a number of sustainability issues are urgently addressed. It was concluded that scientific research has a major role to play in addressing such issues.

INTRODUCTION

Water is probably the most limiting factor in agricultural production in arid and semi-arid regions of the world which constitute about 60% of the land on the surface of the earth and support about 150 million people (Fried and Barrada, 1967). Such areas receive inadequate amount and duration of rainfall leading to under-utilization of agricultural inputs and a concomitant low level of agricultural production. The increasing population pressure in these areas has, however, created increased demand for agricultural products. To meet this demand, more land area has to be brought into cultivation while the areas already under cultivation need to be used more intensively, to increase their productivity. And as Mu'azu and Abdulmumin (1991) noted, this can be achieved only through irrigation. Through increased productivity and production, irrigation is also expected to bring about higher farm incomes and increased standard of living of farmers. The modification in the environment occasioned by irrigation is expected tu check droughts and desertification which constitute serious threat to survival of life in these areas.

The initial reaction of most governments in arid and semi- arid regions of Africa, to the recognition of the significance of irrigation, was the establishment of large-scale irrigation schemes which are highly capital-intensive and require the importation of complex foreign technologies. The failure of most of the schemes to achieve the desired objectives and the serious fiscal crisis experienced by many African countries since the early 1980s have caused a re-thinking of this approach to irrigation development, and emphasis is currently shifting to small-scale irrigation which requires less capital and foreign exchange.

With two-thirds of its total land area covered by the Sahara Desert (Decalo, 1989), and the remaining one-third by Sahel savanna, Niger Republic is a typical example of an arid country in Africa. Substantial increase in agricultural production is almost impossible without irrigation. In apparent recognition of this fact, a number of small-scale irrigation schemes are being established, one of the latest being the Tarka Valley Project (*projet basse vallee de la Tarka*) which has focused on ground water development for small-scale irrigation. Since its inception in 1987, the Project has constructed several tubewells and a few boreholes.

The Tarka Valley Project [*Projet basse vallee de la Tarka* (PBVT)]

The PBVT is an EEC-sponsored Project executed in the Tarka Valley of Niger Republic. The project was established in 1987 and was to operate in two phases, each phase covering a period of five years. The first phase ended in 1991 while the second phase is in progress. The mandate of the Project was to develop ground water resources for irrigation in the Tarka valley of Niger. Under the first phase, 207 tubewells have been completed and handed over to rural farmers. In addition, a number of bore holes equipped with large capacity pumps have been drilled for use by farmers in groups. The project has also loaned several motorized pumps to farmers. Since the project began, no attempt has been made to assess its effects on farmers and their farm lands. But such an evaluation is necessary in order to determine the performance of tubewell/pump irrigation technology and draw implications about its ability to generate a sustainable increase in agricultural production in such a fragile ecological environment.

The Research Problem

A considerable attention has been given, in the literature, to the potentials and limitations of large-scale irrigation in arid areas. In particular, attention has often been drawn to such socio-economic and environmental effects of large-scale irrigation as waterlogging, soil salinity, emergence of harmful weeds, modifications of terrestrial and aquatic environments, population pressure, increase in real and potential health hazards, and displacement of human settlements (Carruthers, 1968; ICSU, 1977; UNESCO, 1978; Essien and Singha, 1991; Misari and Owonubi, 1991; Mu'azu and Abdulmumin, 1991; Odihi, 1994). The implications of these effects for sustainability have also been examined (Kolawole and Scoones, 1994).

Small-scale irrigation, on the other hand, has not received similar level of attention. This is particularly true for Africa where most of the few studies carried out have only examined the potentials and limitations of small-scale irrigation in the year of study (Erhabor, 1982; Baba, 1993). The long-term implications, for the environment and production sustainability, of small-scale irrigation, particularly those based on ground water development, have not received adequate research attention. But the analysis of such implications is necessary to achieve the desired sustainable increase in agricultural production, while minimizing damage to the environment.

Using the area covered by the PBVT in Niger as a case study, this paper first examines the relative potentials of three ground water development technologies as regard their effects on resource use, crop yield, and farm incomes. Then the long-term implications of ground water irrigation in the semi-arid environment are highlighted. Implications drawn are with respect to sustainability of the technologies being introduced, sustainability of water source and sustainability of suitable land.

METHODOLOGY

The Study Area

The area of study was the *basse vallee de la Tarka* (or the Tarka Valley) where the PBVT has embarked on ground water development for irrigation based mainly on tubewells and motorized pumps. The valley lies in the south-eastern part of the Tahoua Province and is located between longitudes 6° and 7° East, and latitudes 13°05' and 14° North. It lies in the Sahel Savanna ecological zone. Annual rainfall is between 500 mm and 600 mm, with a duration of two to four months, usually beginning around May and ending around August. Early maturing and drought-tolerant varieties of millet and sorghum are grown within the short rainy period and most agricultural resources are idle for the remaining period of the year. Irrigation was, therefore, introduced into the area to achieve higher level of resource employment and higher agricultural output. Most of the streams that formerly flowed through the valley have completely dried up, while the remaining few are seasonal and erratic. This, coupled with the high evaporation rate in this environment, would make impounding and storing surface water for irrigation very costly. The only reasonable irrigation strategy is through ground water development, which is the task being undertaken by the PBVT

Sampling, Data Collection and Analysis

Four categories of irrigation farmers were distinguished in the study area. The first category consisted of farmers individually using small motorized pumps with tubewells constructed by the project. The second category included those in the *groupement mutialiste des producteurs* (G.M.P.) who used a common water source. The common water sources were bore holes equipped with large capacity pumps and were also constructed by the Project. Farmers in this category were each allowed to cultivate 0.06 ha only. The third category of farmers consisted of those who constructed their own open wells and used motorized pumps to lift water to their plots, while the fourth category included those who also constructed their own open wells but used traditional water lift devices such as calabash and shadoof to irrigate their fields. A sampling frame was obtained for each category of farmers from which random samples were drawn. The sample size from each category was determined by the size of the category relative to the total number of farmers engaged in irrigation farming in the valley. On the basis of this procedure, 19 tubewell/pump farmers, 17 common water source (G.M.P.) farmers, 7 open well/pump users, and 17 farmers using traditional lift devices were selected, giving a total sample size of 60 respondents. However, only data collected from 51 farmers were analyzed because the 7 open well/pump, and 2 of the tubewell/pump farmers were dropped for inconsistent and unreliable responses. Input-output, inventory, and sales data were collected from the farmers by one of the authors and enumerators between September 1991 and June 1992, using structured questionnaires, in multiple visits. Data collected were analyzed using descriptive statistics, analysis of variance, and a farm budget model. The model was of the form:

$$NFI = GI - VC - FC$$

where
NFI = net farm income, GI = gross income, VC = variable costs and FC = fixed costs.

RESULTS AND DISCUSSION

Resource Use

The mean farm sizes for the different categories of respondents are presented in Table 1. As shown in the Table, farmers using tube-wells and pumps cultivated the largest plots with a mean of 0.49 ha. This was followed by traditional farmers with an average plot size of 0.39 ha. The size of G.M.P. farmers was restricted to 0.06 ha by the Project. These results indicate that the introduction of tube-wells and pumps may have increased average size of farm holdings over the traditional water lift sources. This finding is in agreement with that of Baba (1993) who worked in Bauchi State of Nigeria and reported increases in farm sizes of pump users over traditional (shadoof) users. The smaller farm sizes for farmers irrigating with shadoof and calabashes could be attributed to the low discharge rates and drudgery, associated with these technologies, which limit the amount of land that could be irrigated by any one farmer. Unless improvements are made on these technologies, they could not be relied upon for the desired expansion in the total cultivated land area and increased agricultural production through ground water irrigation.

The respondents' expenditures on hired labor are also presented in Table 1. Tubewell farmers used the highest amount of hired labor, followed by traditional and G.M.P. farmers, respectively. The relatively high expenditure on hired labor by tubewell users could be an indication that this new technology has promoted labor employment in the area. Also presented in Table 1 is the average per hectare fertilizer use by farmers. Tubewell users, traditional farmers, and G.M.P. farmers used an average of 76.50 kg/ha, 67.50 kg/ha and 36.00 kg/ha, respectively. Again, the tubewell and pump technologies appear to have increased fertilizer application over traditional methods. A possible explanation for this could be that farmers who were wealthy and sophisticated enough to acquire tubewells and pumps, also had sufficient funds to purchase more fertilizer.

An important implication of the results presented above is that the tubewell and/or pump technologies have increased the level of resource utilization in small-scale irrigation. This might be a step in the right direction towards achieving one of the objectives of modern ground water development for irrigation which is to increase agricultural production through a more intensive utilization of production resources.

Crop Yield and Farm Income

The major crop grown in the valley is onion. The yield of onion is presented in the fifth column of Table 1 which shows that G.M.P. farmers obtained the highest yield followed by tubewell users, and then the traditional farmers. The G.M.P. and tubewell farmers recorded yield increases of 267% and 36%, respectively, over traditional farmers.

These yield differences are probably due to differences in water availability. Almost all the open wells (used by traditional farmers) and 44% of tubewells dried up before the end of the irrigation season causing water shortage and depressing yields on plots relying on them. Water shortage has also been identified as one of the most limiting constraints, in ground water irrigation, in similar studies conducted in savanna regions of Nigeria (Baba, 1993; Erhabor, 1991; Baba and Etuk, 1991).

Table 1: Resource Use and Crop (onion) Yield*.

Farmer category	Average farm size (ha)	Average expenditure on hired labor (CFA/ha)	Average fertilizer application (kg/ha)	Average yield (kg/ha)
Tubewell	0.49[a]	8433.82[a]	76.50[a]	19188.53[a]
G.M.P.	0.06[b]	7964.71[a]	67.50[a]	45397.76[b]
Traditional	0.39[c]	2829.41[b]	36.00[b]	12341.29[a]

* Figures in a column with the same superscript are not significantly different; significantly different (at 5% level), otherwise.
Source: Field survey, 1991/92.

The costs and returns in onion production under the different irrigation technologies are presented in Table 2. As depicted in the table, the net farm income variation followed the same pattern as that of the yield with G.M.P. farmers obtaining the highest, followed by tubewell users and traditional farmers in that order. The variation in income, therefore, could be attributed mainly to variation in yield which was, in turn, dependent on water availability.

Table 2: Costs and Returns in Onion Production (CFA/ha).

Farmer Category	Fixed Costs	Variable Costs	Total costs	Gross Income	Net Farm Income
Tubewell	114300	125500	239800	1420343	1180543
G.M.P.	80300	140500	220800	1620312	1399512
Traditional	35300	79750	1115050	1050555	935505

Source: Field Survey, 1991/92.

SUSTAINABILITY IMPLICATIONS

The sustainability implications of ground water development for irrigation in an arid environment such as the Tarka valley could be discussed under three headings: (1) sustainability of technology, (2) sustainability of water source, and (3) sustainability of suitable land.

Sustainability of Technology

Ground water development in the area is based mainly on the sinking of tubewells and, to a lesser extent, construction of bore holes. As indicated earlier, irrigation with tubewell appears to have increased crop yield over traditional methods. It must be noted, however, that 44% of the tubewells dried up, along with most of the open wells, before the end of the season, thereby reducing yields of farmers using these technologies. This raises the question as to whether tubewell is the most suitable technology to replace traditional technologies in the study area. In contrast, farmers belonging to the G.M.P. obtained sufficient water throughout the season and realized the highest yield among all the farmers. The G.M.P. farmers obtained water from a bore hole through a central pump. In such arid areas, it would seem, bore hole may be a more reliable technology than tubewell in meeting irrigation water requirements.

Both of the water tapping technologies under discussion, however, depend on fuel as the source of power. This introduces another dimension to the sustainability question. Although the cost of fuel constituted only 4% of production cost in this study, it is a recognized fact that fuel prices are on the increase on the African Continent. There is a possibility that profitability of irrigation with these technologies could drastically decline if the current waves of price increases are sustained. This poses serious threat to sustainability of increased production because lower returns could discourage farmers from further investment in these irrigation systems.

Sustainability of Water Source

An important question to ask in arid land irrigation is whether the ground water would continue to support irrigation indefinitely. To answer this question, we need to examine some aspects of the hydrological cycle particularly with respect to the balance between rainfall and evapotranspiration (ET) in the region. During irrigation, ground water is brought to the soil surface where it is lost mainly through ET and seepage. While some of the latter may return to the ground water, the former is lost to the atmosphere. The only way it could return to the ground water table is by annual recharging through rainfall. This explains why the amount of rainfall as compared to the level of ET is important in determining the level of ground water table after every season of irrigation. If rainfall exceeds ET, there is hope that ground water irrigation could continue for a long time; otherwise, continuous irrigation would deplete ground water and reduce water availability for irrigation.

In an analysis of rainfall and ET patterns across various savanna ecological zones, Owonubi *et al.* (1991) noted that potential ET (the upper limit of vapor volume which can be absorbed by the overlying air mass) exceeds annual rainfall by more than 1,600 mm in the Sahel Savanna. Although the determination of actual ET, depending upon the structure and instantaneous conditions of the vapor producing system, as suggested by UNESCO (1978), is required to be able to make conclusive comparison between rainfall and ET, the magnitude of this figure is an indication that it is possible that rainfall in a semi-arid region, such as the one studied, may be unable to fully compensate for the water lost to the atmosphere. Continuous irrigation in such an area could therefore, lead to a decline in the ground water table, not only in the irrigated fields but also in the adjoining land areas, thereby reducing water availability for further irrigation. Such a scenario could reduce profitability through its effect on crop yield. A declining ground water table could also reduce profitability by increasing pumping cost, which, as Carruthers (1968) pointed out, is directly proportional to pumping height. As the pumping height continues to increase, a point will be reached where the pumping costs exceed the value of the water obtained.

Furthermore, a declining water table would result in drier top soil in the irrigated fields' and areas nearby, since it would reduce the chances of water, which moves upward by capillarity, coming close to the surface. Such drier conditions would further reduce vegetation cover and worsen the problems of wind erosion and desertification in an already fragile ecological environment. One of the arguments often made in support of irrigation is that it aids in checking these environmental hazards. It is paradoxical that in the case of using ground water in an arid environment, irrigation may, in the long run, actually promote them. The conclusions reached here are, however, tentative since ground water flow could also recharge the water table. Nevertheless, monitoring of ground water table appears crucial for long-term sustainability.

Sustainability of Suitable Land

Ground water has high salt concentration. When brought to the surface or root zone, most of the water is lost through ET, leaving the salt behind. Continuous application of ground water leads to the accumulation of salts on the soil surface or in the top soil resulting in soil salinity. The salinity of the soil makes it unsuitable for crop growth. In areas with high rainfall, salinity is reduced by leaching of the soil and good drainage systems. But if salinity develops in an arid area, it could be a serious threat to crop production because the rainfall received may not be sufficient to leach the salts out of the root zone. Crop yield and farm incomes would reduce very drastically, thereby endangering sustainability of increased production expected from irrigation.

RECOMMENDATIONS AND CONCLUSION

In order to avoid the sustainability problems which could emanate from ground water development for irrigation in arid and semi-arid regions of the world, which constitute more than 60% of the land on the surface of the earth, scientific research has to be treated as a vital aspect of any irrigation development project in these areas. A great challenge to scientists in this respect is to develop alternative cheap and renewable energy sources for lifting water for irrigation in view of the rising cost of petroleum products. In particular, the possibility of developing suitable animal, wind and/or solar-powered technologies for lifting water should be given concerted attention. In most arid and semi-arid regions of Africa, animal ownership is already a custom of the people and technologies based on animals should not be completely foreign to people in such areas. In addition, with their sparse vegetation cover, these areas present excellent conditions for technologies based on solar energy reception and wind speed.

Research is also needed to continuously monitor the ground water table and changes in the physico-chemical properties of irrigated soils (particularly with respect to salinity) and prescribing appropriate remedies whenever anomalies are detected. Further studies on water conservation techniques would also be required to reduce ET and other forms of water loss from the soil.

In conclusion, the results of this study have indicated that modern ground water development for irrigation in a semi-arid environment has potentials for increasing resource use and agricultural output in the short run. To realize these potentials on a long-term basis, however, a number of precautions mainly in the area of research would have to be taken. Otherwise, ground water development could have adverse effects on the already fragile environment and precipitate serious sustainability problems.

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