SOCIO ECONOMIC IMPACTS OF AGRICULTURAL LAND DRAINAGE – A STUDY FROM NORTH WEST INDIA [1]

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ABSTRACT

To combat waterlogging and soil salinity, subsurface drainage/SSD has been recommended. Drainage needs have developed in 10-15million hectares in arid and semi-arid regions and in some 45 million hectares in irrigated areas throughout the world. Due to long neglect of the drainage problem, at the global level annual losses in the order of US $ 11 billion have been reported from the waterlogged saline area. Also in India, waterlogging and soil salinity take their toll. Diverse statistics show that the twin problem is threatening agricultural production on 5.5 million to 13 million ha. Roughly one million hectares are so seriously affected, that agricultural production had to be abandoned completely. To control and manage the problem in the most fertile, irrigated areas, investment in drainage was initiated in the Northwest region of India. This paper attempts to assess the benefits of installing subsurface drainage for salinity control. Specific objectives of the paper are: (i) to assess the impact of subsurface drainage on efficiency, equity and sustainability of agricultural production, and (ii) to examine the factors affecting the sustainability of the technology.

Decomposition analyses were made to assess the absolute contribution of drainage to farm income. Gini concentration ratios were computed in comparable areas *with* and *without* subsurface drainage systems to measure differences with respect to equity as a result of drainage. In the drained area, also a *before* and *after* comparison was made. Lorenz curves were used to visualise the inequalities between the drained and non-drained area, and in the drained area *before* and *after* drainage installation. The result of the calculations reveals several farm-level benefits of subsurface drainage. These include (i) substantial increase in farm income, (ii) crop intensification, and diversification towards high value crops, and (iii) generation of employment opportunities. Apart from that, the results also show that subsurface drainage will result in a reduction of income inequalities across farm producers. The decomposition analyses show that in the Gohana area drainage resulted in a 40 to 70 per cent yield increase. However, in spite of its economic, social and environmental benefits, the acceptance of the subsurface drainage technology is always questioned. Some specific reasons for this are discussed in the present paper. These are:: (i) indivisible nature of the technology, (ii) lukewarm attitude with respect to collective action by the potential beneficiaries, (iii) conflicting objectives among beneficiaries, and (iv) growing numbers of free riders. This occurs due to the absence of appropriate institutional arrangements. The analysis showed that, in spite of its high potential, the subsurface drainage technology might not yield the desired results in the absence of proper institutional arrangements.

Keywords: Economic effect of subsurface drainage, decomposition analysis, Cobb-Douglas analysis, Gini-concentration, institutional arrangements, sustainability, free riders

1 INTRODUCTION

Agricultural land drainage has been practised for millennia. Although it is recognised that under various conditions drainage is an important means to secure sustainable agriculture, it is nevertheless a highly neglected factor. Only researchers and environmentalist are paying increasing attention to the drainage needs. Nevertheless, there are few reliable estimates on the effect of waterlogging and soil salinity on agricultural production at farm level, regional level, or at global scale. Since land degradation is location specific and spatial in nature, the magnitude of the losses varies from area to area. World-wide, the extent of the damage due to *salinisation* is ranging between 12 to 36 percent of the annual gross production value. It has been estimated that, at the global level, the annual loss from 45.4 million ha of salt affected lands in irrigated areas may amount to US $ 11.4 billion (Ghassem et al., 1995). Unfortunately, in India, data on the occurrence and spread of waterlogging and soil salinity in the country are varied and sketchy. The existing estimates range from 5.5 million to 13 million ha (Joshi et al 1992). There are some more recent estimates. It has been reported that in Northwest India an area of 0.7 to 1.0 million ha is already seriously affected by waterlogging and soil salinity. Recent estimates pointed out that the damage due to water logging and soil salinity in this area is in the order of 10 to 15 per cent of the annual gross production per hectare as compared to the yields obtained in the non-affected land. The total annual loss in Haryana is about Rs 1670 million (about US $ 37 million) (Datta & De Jong, 2002).

There are basically three reasons for installing agricultural land drainage systems: (1) for trafficability, so that seedbed preparation, planting, harvesting, and other field operations can be conducted in a timely manner, (2) for protection of crops from excessive soil water conditions, and (3) for salinity control. This paper attempts to assess the impact of the installation of subsurface drainage for salinity control. Specific objectives of the paper are: (i) to assess the economic effect of subsurface drainage on crop production, income level, efficiency, equity, and the environment; (ii) to quantify the contribution of drainage by comparing the productivity of drained areas with the productivity of comparable non-drained areas; (iii) to highlight the factors which are affecting the adoption of drainage by the farming community.

2 DATABASE & ANALYTICAL TOOLS USED

The socio-economic survey was conducted in the Gohana area, situated in the Gohana Sub-Division of the Sonipat District of Haryana. The district was selected with a view to the extent of the waterlogged, saline area. In Haryana, about 207,000 ha, or 54 percent of the geographical area, is affected by waterlogging and soil salinity. For the study, five villages, constituting the Gohana area, were selected. Together, these villages cover an area of about 4,600 ha. In the area, there are about 2,150 households and the population is some 14,000.

In this area, about 250 sample plots were selected with the help of a grid system. Subsequently, the owners of the sample plots were identified with the help of revenue records and maps. In the selected sample plots, soil samples, crop cuttings, and water table measurements were done. Apart from this, socio-economic surveys were carried out amongst the owners and/or cultivators of the sample plots. Since some of the farmers possessed two selected sample plots, the plot and farm surveys were conducted among some 225 farmers' families. The monitoring and evaluation programme of the project aimed at assessing the potential contribution of drainage technology for salinity management to crop production.

To determine the absolute effect of drainage on gross crop income decomposition analysis was used. Decomposition analysis is a mathematical technique that can disaggregate and quantify a difference in an observable quantitative variable into its components. More simply, the technique provides a method to quantify the intervening factors of a difference such as *before* and *after* or *with* and *without* situation. Bisaliah (1977) and Joshi et al. (1992, 1994) used a similar technique for wheat and other crops.

Since paddy and wheat are the main crops in the wet and dry season, respectively, these two crops were chosen for the analysis. The approach assumes that in the non-drained area, salinity build-up will directly influence the crop yields. To establish the relationship, a Cobb-Douglas (C-D) form of production function was employed. Several explanatory variables, defined in different ways, were included to estimate the production function. The following functional form and variables were selected for further analysis:

$Y = A\ S^b F^c\ I^d\ K^e\ L^f\ e^u$ .... (1)

Where, Y is the gross income from paddy or wheat (Rs/Acre); S is cost of seeds (Rs/Acre); F is cost of fertiliser (Rs/Acre); I is cost of irrigation (Rs/Acre); K is cost of capital (includes cost of chemicals and machinery use, Rs/Acre) and L is the cost of labour (Rs/Acre). Since fertiliser application has a direct effect on salinity, it was considered separately and not added into capital. The coefficient a refers to any kind of shift in the production function as a result of technological change. The exponents b, c, d, e, and f are the regression coefficients of the respective variables (u is the error term and e is the base of the natural log).
The change in gross income between drained and non-drained, salt-affected soils was decomposed into (i) changes due to drainage effect and (ii) changes due to reallocation of inputs.

2.1 Drained area:

$\text{Log } Y_d = \text{Log } A_d + b_d \text{ Log } S_d + c_d \text{ Log } F_d + d_d \text{ Log } I_d + e_d \text{ Log } K_d + f_d \text{Log } L_d$ ………….(2)

2.2 Non-drained area:

$\text{Log } Y_{ud} = \text{Log } A_{ud} + b_{ud} \text{ Log } S_{ud} + c_{ud} \text{ Log } F_{ud} + d_{ud} \text{ Log } I_{ud}\ e_{ud} \text{ LogK }_{ud} + f_{ud} \text{ Log } L_{ud}$ …………..(3)

Taking the difference between (2) and (3), adding some terms, and subtracting the same terms yield the following:

$\text{Log } Y_d - \text{Log}Y_{ud} = (\text{Log } A_d - \text{Log } A_{ud}) + (b_d \text{ Log } S_d - b_{ud} \text{ Log } S_{ud} + b_d \text{ Log } S_{ud} - b_d \text{ Log } S_{ud}) + (c_d \text{ Log } F_d - c_{ud} \text{ Log } F_{ud} + c_d \text{ Log } F_{ud} - c_d \text{ Log } F_{ud}) + (d_d \text{ Log } I_d - d_{ud} \text{ Log } I_{ud} + d_d \text{ Log } I_{ud} - d_d \text{ Log } I_{ud}) + (e_d \text{ Log } K_d - e_{ud} \text{ Log } K_{ud} + g_d \text{ Log } K_{ud} - g_d \text{ Log } K_{ud}) + (f_d \text{ Log } L_d - f_{ud} \text{ Log } L_{ud} + f_d \text{ Log } L_{ud} - f_d \text{ Log } L_{ud})$ ......…………..(4)

Rearranging terms in equation (4) yields the following:
$\text{Log } (Y_d/Y_{ud}) = \text{Log } (A_d/A_{ud}) + [(b_d - b_{ud}) \text{ Log } S_{ud} + (c_d - c_{ud}) \text{ Log } F_{ud} + (d_d - d_{ud}) \text{ Log } I_{ud} + (e_d - e_{ud}) \text{ Log } K_{ud} + (fd - f_{ud}) \text{ Log } L_{ud}] + [b_d \text{ Log } (S_d/S_{ud}) + c_d \text{ Log } (F_d/F_{ud}) + d_d \text{ Log } (I_d/I_{ud}) + e_d \text{ Log } (K_d/K_{ud}) + f_d \text{ Log } (L_d/L_{ud})]$ ....(5)

Equation (5) apportions approximately the differences in gross income per hectare between drained (salinity-free) and non-drained (salt-affected soils) into two components. The sum of the first two bracketed components on the right hand side indicates the drainage effect. The third bracketed term measures the contribution of changes in input levels between the two situations.

Lorenz curves were used to depict the inequalities in income on land *with* and *without* drainage, and on the same land *before* and *after* drainage. Since the studied drained and non-drained areas are 'comparable', the differences between *before* and *after* and *with* and *without* are small.
Gini concentration ratios (GCR) were also computed in the study areas *with* and *without* subsurface drainage to measure difference in inequalities in income in the salt-affected and non-affected lands.
Finally, issues related to large-scale adoption of drainage are discussed based on the experience gained in different drainage projects.

3 RESULTS AND DISCUSSION

3.1 Drainage Investment

Given the present scarcity of financial resources, priority setting for investment in resource development is strongly guided by the demand driven forces. Land augmentation or 'horizontal development' through reclamation will be needed for feeding the rural masses only when the potential productivity levels of the non-affected (normal) lands will have been realised, in other words, when the 'saturation point' has been reached. Then, there is no more scope for investment in 'vertical development'.

At this 'threshold level', investment in 'horizontal development' will be needed to break the stagnant level of production. However, at 'threshold level' returns to investment in 'horizontal development' will be a big question mark because it will be difficult to show its financial feasibility at farm, regional, and at national level.

Therefore, investment at 'threshold level' will rather be guided on the ground of scope for further diversification and long-term sustainability through conservation of the natural resources. The financing of such type of investment may be feasible for the developed countries where the scope for 'horizontal development' is more or less limited and increasing of production is only possible through 'vertical development'.

In the Indian context, past experience shows that investment in land reclamation was done only after the production potential of the non-affected (normal) soils was reached (Datta & Joshi, 1990).

Recently Smedema (2002) observed rightly that "The 'saturation point' and the 'threshold level' are useful concepts for the opportunity driven drainage development of rain-fed land, but less for drainage for salinity control of irrigated land. In the latter case, drainage is often not a choice, but a dire necessity to salvage a valuable natural resource from degradation"

3.2 Drainage Costs and Economic Feasibility

To control the water table in areas underlain by groundwater of poor quality, subsurface field drainage systems will have to be installed and to be connected with the main surface drainage system. Earlier research in Haryana has sown (Datta et al., 2000) that drainage will be economically feasible, if manually installed systems can be implemented at the cost of Rs. 25, 000/ha. Mechanically-installed drainage systems would also be justified at the same cost level (Datta et al., 2002). However, mechanised installation of subsurface drainage systems at the rate of Rs. 43,000-45, 000 per ha, as was recently done in the framework of the Haryana Operational Pilot Project/HOPP, is much less cost-effective and not economically feasible under the circumstances in the area. Hereby, we have to make the reservation that, in an irrigated area, cost-benefit analysis for drainage alone is not correct. The benefits obtained earlier, as a result of the shift from rain-fed to irrigated agriculture, must be taken into account in assessing the feasibility of drainage. For, in arid and semi-arid regions, irrigation development without drainage is, in principle, unsustainable.

Therefore, now agricultural development in Haryana has reached the 'threshold level' at which drainage becomes a critical constraint for further advancement, and investment in drainage is essential, one should look beyond the momentary economic feasibility of drainage development alone. Moreover, in view of the threat of losing very scarce and highly valuable agricultural land, drainage development is a must. It may also be observed that, although the process of salinisation is mostly slow, intervention in terms of drainage development should be started as soon as the *salinisation* process starts, because it makes no sense to let the farmers suffer great losses over long periods before installing the long overdue drainage system. In the problem areas, only drainage development will make an end to the stagnation of agricultural production and the decrease in welfare of the rural society.

3.3 Drainage Impacts

3.3.1 Direct impact on water table

To monitor the depth of the water table, 40 observation wells were installed in an area of 2,000 ha in the Gohana Block of Sonepat District. Twenty-seven observation wells are located in the area of 1,000 ha, where in the meantime, drainage systems have been installed, and 13 points in are in the non-drained area.

At 500-m grid points, the depth of the water table was measured monthly and analysed. The water table levels were monitored during 3 years. In the study area, depths of the water table fluctuated from zero to 3.95 m in the study area.

After the installation of subsurface drainage systems the water table levels went down. In the non-drained area, the water table remained shallower, as compared to the levels in the drained area (Table 1). Where the pumps were operated properly, the depth of the water table in the drained area remained below 1.00 m during the whole growing season of the *rabi* (winter) crops.

Farmers reported that the 20 to 50 per cent crop losses during *kharif* (summer season) were mainly due to heavy rainfall in combination with local storms, which cracked the rice stems causing the nearly matured grains to rot in standing water. After the installation of subsurface drainage, the positive impact is not only an improvement in crop yield in the *kharif* season, but also that the following *rabi* crop can be sown in time. Another observation of the farmers in the drained area was that most of the waterlogged, saline fallow lands were reclaimed and brought back into crop production.

3.3.2 Direct impact on soil salinity

Monitoring of soil salinity and crop yields before and after drainage is convenient for an impact assessment of installing a subsurface drainage system in waterlogged, saline lands. To this end, soil and crop samples were collected at a large number of sample plots, at the harvest of the *rabi* crops. Hereby the same grid pattern was used as in the years before drainage development, and the results of the analyses were compared with the initial values of 1995-96 in the drained, as well as in the non-drained area. The installation of subsurface drainage systems was started in 1997 and completed in June 1999. At the harvest of the *rabi* crop l999-2000, the average salinity levels in the drained and in the non-drained control area were 4.6 and 9.2 dS/m, respectively. At the harvest of the *rabi* crop l995-96, the average salinity level was 7.1 dS/m in the whole non-drained area, indicating a 35 per cent decrease in salt content after the installation of subsurface drainage in part of the area. Block wise analysis in the drained area also shows the same picture. In some of the SSD blocks, average soil salinity decreased from 9.7 to 66.3%, whereas in the non-drained area the average salinity level increased from 9.0 (1995-96) to 9.2 (1999-00) indicating a small increase within two years.

3.3.3 Indirect impact on cropping pattern and intensity

During the period 1986-90, the major *kharif* crops were paddy, jowar, and sorghum. Respective percentages of those crops were 11, 7, and 7. But after the installation of drainage the cropping intensity increased dramatically and the respective shares of the above-mentioned crops changed to 61, 14, and 3 per cent, respectively. The area under paddy increased tremendously, due to a spectacular increase in the number of shallow wells for irrigation.

In *rabi*, wheat is the most important crop, covering 81 percent of the area in the post drainage period. This is an increase of about one-third over the 60% during 1986-1990. A number of other crops are grown as well, but each of them occupies only a few per cent of the land. The perennial crop grown in the area is sugar cane. There were no changes in area. The crop still occupies about 5 per cent of the cultivable area.

In the study area, the cropping intensity has drastically increased. It was reported that, in the period 1986-90, the cropping intensity in *kharif* was 35 per cent only; whilst in the *rabi* season it was 82 per cent. The annual cropping intensity was thus 117 per cent. In the post drainage period (1999-2000), the cropping intensity during *kharif* was 83 per cent and in *rabi* season it was 92 per cent. Thus, annual cropping intensity increased to 175 per cent.

3.3.4 Impact on crop yield:

Wheat is the most important crop grown in the Gohana area. In 1994-95, wheat yield was as high as 3.7 ton/ha. It was higher than the district and state averages for that year, which were 2.6 and 2.7 ton/ha respectively. The yields are, generally, far below potential yield levels and show a declining trend as can be seen from district statistics. The reason for this is most probably the deterioration of the agricultural resource base because of aggravated problems of waterlogging and salinity.

During 1995-96, paddy and wheat yields in Gohana area were about 1.8 and 3.1 ton per ha respectively. The average wheat yields in the drained and non-drained areas were 3.6 and 2.4 ton/ha, respectively (Table 2), indicating a significant increase in wheat yield due to the subsurface drainage system. (Drainage) block wise increase in wheat yield ranged from 9.7 to 54.0 per cent, as compared to the *rabi* l995-96 wheat yield. The overall net yield increase due to subsurface drainage was about 49 percent.

From the above analysis it is clear that on-farm direct benefits of subsurface drainage, which controls the water table and enables the process of desalinisation through leaching of the salts, are substantial. This is a combined result of the following changes: (i) a considerable increase in cropping intensity; (ii) a shift in cropping pattern towards more remunerative crops; (iii) a significant increase in crop yields; (iv) an increase in gainful employment, and (v) a conversion of abandoned, marginal lands into agricultural use. In other words, subsurface drainage helps to improve farm incomes by creating proper conditions for crop intensification and crop diversification, for overcoming crop calendar constraints, for allowing mechanisation of farm operations, for enhancing the impact of fertilisers and other inputs, for lowering production costs, and for mitigating adverse environmental impacts.

In general, SSD will make the agricultural sector more competitive, efficient and sustainable.

3.4 Contribution of Drainage

To quantify the absolute contribution of drainage to the increase in farm income, a regression analysis was carried out. The estimated regression equations (equation nos. 2 & 3) for drained and non-drained areas in Gohana are presented in Table 4a and 4b for paddy, and in Table 5a and 5b for wheat. Most of the selected variables, namely seed, fertiliser, labour and capital were statistically significant at different probability levels, except labour, both in the drained and non-drained areas, and irrigation for paddy in the non-drained area. The value of R^2 ranged from 33% to 68% for wheat, whereas for paddy it was about 57% both in the drained and non-drained area. The F values were high for both cases. May be, including different salinity levels as one of the variables in our production function will improve the R^2 value for wheat. The expected positive production elasticities of different factors indicated the response on gross (paddy and wheat) income. As an example, a 1% increase in fertiliser expenditure at mean level (6.4468, see Table 3b) increased the income from wheat in the drained area with about 0.43 % and in the non-drained area with 0.22% only. Similarly, in the case of paddy, the effect of increasing fertiliser expenditure by 1% (where the mean level is 2.8564, see Table 3a) will yield an increase of 0.54% in paddy income in the drained area, and 0.47% in the non-drained area. From these observations, we may conclude that drainage helps to make fertiliser use more efficient, thus reducing the cost of production.

The results of the decomposition exercise, derived from the results shown in Table 4a and 4b, and in Table 5a and 5b, are reported in Table 6. The figures in Table 6 indicate that the drainage technology accounted for about 40% of the increase in income in paddy areas. In wheat areas, the corresponding figure for drained areas was 72%. These values indicate that with the same level of resource use in the drained and in the non-drained, salt-affected areas, gross income would increase by 40% in paddy the areas and by 72% in the wheat areas of Gohana. It is important to note that seeds, fertilisers, irrigation and capital cost were positively related and statistically significant at different probability levels. It is interesting to note that in the non-drained areas none of the factors was negatively related with income. This may be due to the fact that there is still scope to enhance income through those inputs also in the non-drained areas. However, field observations indicated that farmers are reluctant to use best agricultural practices in the salt-affected areas. They are giving less priority to these areas, as compared to their non-affected areas. Smedema (2000) reported a 10-15% contribution of drainage in the total world food production.

3.4.1 Reducing Income Disparity:

It is generally argued that in canal irrigation systems, there is always a ‘head’ versus ‘tail’ problem related to the distribution of the available irrigation water. By the very nature of the canal system, the higher-lying, better-drained land is in the head-end and the lower lying, naturally poorer drained lands, in the tail end. Generally, the head-end farmers had earlier and better access to water and better opportunities for development than tail-end farmers. This situation is often reinforced over time as much of the progress and development bypasses the poor or can not be beneficially used by them, due to the poor drainage conditions of the land. The naturally poorer drainage conditions, together with the inadequate and unreliable irrigation water supply, have often resulted in severe waterlogging and *salinisation* problems in the tail-end land. Crop yields are often low and part of the land has become fully unproductive. Improved drainage, in combination with improved irrigation water management, can under these conditions be an effective instrument for combating poverty (Smedema, 2002).

To show that drainage technology helps to reduce income disparities, Lorenz curves were derived from the income data of the drained Gohana HOPP area and from the non-drained Control area (Figure 1 & 2). With the same data also Gini Concentration Ratios (GCR) were calculated for the situation *before* and *after* drainage, and for the situation *with* and *without* drainage. Before drainage, the GCR in the project area was about 23 percent (Table 7), but after drainage it was only 3 percent. This is a clear indication that drainage technology maximises the distribution of welfare gains (also to the weaker sections of society) by conserving the land and water resources. The resulting reduction in income inequality is about 20 per cent. The Lorenz curves (Figure 1 & 2) also support this by clearly depicting the disparity between drained and non-drained area. The inequality curve is more prominent in case of the non-drained area (Figure 2), whereas in the drained area the disparity is less.

In terms of employment generation, drainage helps to create additional gainful employment during the installation stage, and subsequently for intensified crop production. About 85 additional labour days per hectare were created.
Apart from this, drainage development it helps to create additional work and income in the industrial sector. About 60 to 70 per cent of the investment in drainage go to the industrial sector, which delivers drainpipes and other drainage materials.

Improved drainage also produces a number of social and environmental benefits like, improved public health, improved sanitation, safe water supply, improved animal health, protection of rural infrastructure, which enhance rural welfare.
Recent research findings from Pakistan indicate that the derived additional benefits can be quite substantial, and do significantly contribute to the feasibility of investment in improved drainage (IPTRID 1999; Scheumann and Freisem 2001).
Agricultural drainage projects in Japan always include the provision of improved village sanitation.
Drainage Boards in the Netherlands not only deal with the control of excess water, but also with water quality control.

It is highly relevant to recognise that much of the early drainage developments were not for agricultural, but for public health purposes, in order to reduce the prevalence of marshy conditions in populated areas to combat malaria and other water related diseases. Subsurface drainage not only improved land for agricultural production, but is also helped to control diseases carried by the mosquitoes and black flies leaving in the wet areas. It is also reported that the drainage facilitated the settlement of immigrants in North America (USDA, 1955). In spite of the manifold economic, social and environmental benefits, the adoption of subsurface drainage is always questioned. The reasons for this will be discussed in the following section.

3.4.2 Constraints towards the Adoption of the Technology

Constraints towards large-scale adoption of drainage are discussed on the basis of the experience gained in various drainage projects. The study of small-scale subsurface drainage projects in Haryana and Gujarat revealed a number of serious constraints towards the adoption of the technology (Datta & Joshi, 1992). The most important are: (i) the indivisible nature of the SSD technology, (ii) increased economic differentiation and socio-political factionalism and (iii) internal heterogeneity and inequities.
In order to overcome such type of problems a participatory approach in project development is generally advocated. But there are several serious constraints, which may hamper the success of people's participation in implementing drainage projects. Some of these are: (i) the problem of free riders, (ii) the lukewarm attitude of potential beneficiaries to participate, (iii) conflicting objectives of different (groups of) beneficiaries, (iv) poor perception of the objectives of the project, (v) factionalism in the village, (vi) strong dependence on governmental patronage, and (vii) a completely eroded culture of group action and sharing systems (Datta & Joshi, 1992).

No attraction to an individual farm household on investment to prevent or cure the degraded lands

Despite yielding high dividends, collective action is required to realise the potential benefits from SSD due to indivisible nature of the technology. Our analysis concluded that the technology without institutional arrangement might not yield desired results. A technology with high potential benefits may not make a difference and can be abandoned in the absence of required institutional arrangements.

4 CONCLUSIONS

In spite of the high potential economic, social, and environmental benefits, the adoption of the subsurface drainage technology is always questioned.
Our study in the Gohana Pilot Area revealed substantial farm-level benefits as a result of installing subsurface drainage. This is a combined result of the following changes: (i) a considerable increase in cropping intensity; (ii) a shift in cropping pattern towards more remunerative crops; (iii) a significant increase in crop yields; (iv) an increase in gainful employment, and (v) a conversion of abandoned, marginal lands into agricultural use.
In other words, subsurface drainage helps to improve farm incomes by creating proper conditions for crop intensification and crop diversification, for overcoming crop calendar constraints, for allowing mechanisation of farm operations, for enhancing the impact of fertilisers and other inputs, for lowering production costs, and for mitigating adverse environmental impacts.
In general, SSD will make the agricultural sector more competitive, efficient and sustainable.

Apart from this, subsurface drainage proved to contribute greatly to the mitigation of income inequalities across farmers. And, drainage development triggers forward and backward linking activities, such as the production of drainpipes and other drainage materials, increased trade in fertilisers and other farm inputs, and in farm outputs (multiplier effect).

The decomposition analyses show that in the Gohana Pilot Area the installation of subsurface drainage resulted in a 40 per cent increase in gross income of the paddy crop and a 70 per cent increase in gross income of the wheat crop.
However, technology alone is not sufficient. A technology with high potential benefits may not make a difference in the absence of proper institutional arrangements. Therefore, technical development must go hand in hand with institutional development to realise the potential of the drainage technology.

Given the fact that agriculture in Haryana has reached the 'threshold level' at which drainage becomes a critical constraint for further advancement, and investment in drainage is essential, one should look beyond the momentary economic feasibility of drainage development alone.
Moreover, in view of the threat of losing very scarce and highly valuable agricultural land, drainage development is a must. The Government should take its responsibility for saving the scarce, high potential agricultural lands and preventing affected rural communities from total impoverishment. Therefore, one-quarter or one-third of the annual budget for irrigation development should be reserved for large-scale drainage to prevent valuable irrigated land from complete deterioration.

Although the process of salinisation is mostly slow, drainage development should start as soon as the problem arises, because it makes no sense to let the farmers suffer great losses over long periods before installing the long overdue drainage system.

In the problem areas, only drainage development will make an end to the stagnation of agricultural production and the decrease in welfare of the rural society.

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Table 1 Water table depth in the Gohana area before (1995-96) and after (1999-00) SSD (in m)

Area	**Before SSD**				**After SSD**			
	March	June	September	December	March	June	September	December
Range	0.42-1.24	1.23-2.79	0.48-1.52	0.31-1.95	0.12-1.47	1.31-2.65	0.64-1.22	0.34-1.30
Average in the drained area	0.79	1.91	0.83	1.00	0.865	1.90	0.89	0.88
Average in the non-drained area	0.63	1.24	0.48	0.59	-	-	-	-

Table 2 Effect of subsurface drainage system on crop yield (ton/ha)

Crops	Area	Before SSD (1995-96)	After SSD *(1999-00)*	*Percentage of yield increase (+)/ decrease (-)*
Wheat	Without drained	2.94	2.43	- 17.3
	With drained	3.07	3.61	+17.6
Paddy	Without drained	1.3	1.2	-7.69
	With drained	1.4	1.7	+21.43
Pearl Millet	Without drained	0.80	0.75	-6.25
	With drained	0.88	1.23	+39.77

Table 3a Average log values of the selected input-output parameters for paddy in Gohana during 2000.

	Gross income	Seed cost	Fertiliser cost	Irrigation cost	Capital cost	Labour cost
Drained area	3,792947	2,041648	2,856421	2,816473	3,169412	3,014069
Non-drained area	3,730641	2,060694	2,82138	2,803338	3,136155	3,006405

Table 3(b) Average log value of the selected input-output parameters for wheat in Gohana during 1999-00

	Gross income	Seed cost	Fertiliser cost	Irrigation	Capital cost	Labour cost

				cost		
Drained area	2.7067	5.72008	6.44685	5.11053	7.31951	7.29875
Non-drained area	2.55098	5.63450	6.43431	5.13869	7.30254	7.31686

Table 4a C-D production function of paddy in the drained area of Gohana during 2000

Regression Statistics	Coefficients	
Multiple R	0,753438	
R Square	0,567668	
Adjusted R Square	0,535405	
Standard Error	0,164021	
F value	17.59472	
Observations	73	
Factors		Standard Error
Intercept	-2,71976*	1,180255
Seeds	0,864683*	0,318242
Fertiliser	0,544942*	0,16262
Irrigation	0,365422**	0,226418
Capital costs	0,983354*	0,48664
Labour	-0,31688	0,347129

Table 4(b). Production function of paddy crop (C-D) in the non-drained area of Gohana during 2000.

Regression Statistics	*Coefficients*	
Multiple R	0,755929	
R Square	0,571428	
Adjusted R Square	0,529411	
Standard Error	0,161566	
F-value	13,59996	
Observations	57	
Factors		Standard Error
Intercept	-2,82005**	1,46345
Seeds	0,164698	0,297916
Fertiliser	0,472837*	0,182007
Irrigation	-0,19751	0,209034
Capital costs	1,330303*	0,545551
Labour	0,418737***	0,368083

*, **, *** Significant at 1%; 5% and 10% probability level.

Table 5a C-D production function of wheat in the drained area of Gohana during 1999-00

Regression Statistics	Coefficients	
Multiple R	0,825091	
R Square	0,680776	
Adjusted R Square	0,668007	
Standard Error	0,193933	
F-value	53,31488	
Factors		*Standard Error*
Intercept	2,065399*	0,79695
Seeds	0,238736**	0,120019
Fertiliser	0.427158*	0,065751
Irrigation	0.072175**	0,035323
Variable costs	0,341752*	0,072924
Labour	0,10439	0,146858
Observations	131	

Table 5(b). C-D production function of wheat in the non-drained area of Gohana during 1999-00

Regression Statistics	*Coefficients*	
Multiple R	0,576962	
R Square	0,332885	
Adjusted R Square	0,298139	
Standard Error	0,195159	
Observations	102	
Factors		*Standard Error*
Intercept	4,579794*	0,806457
Seeds	0,098951*	0,046708
Fertiliser	0,220497**	0,145183
Irrigation	0,096959**	0,050555
Variable costs	0,322056*	0,090427
Labour	0,037118	0,091264

*, **, *** Significant at 1%; 5% and 10% probability level.

Table 6 Decomposition of factors contributing to yield and income differences between the drained and non-drained area of Gohana during 1999-0.

Items	Percentage attributable	
	Paddy	Wheat
Sources of change		
Technological	39,49	71,51
Changes of input	60,51	18,33
(i) Seed	-3,90	13,12
(ii) Fertilisers	-26,43	3,44
(iii) Irrigation	30,65	-1,31
(iv) Capital	52,49	3,72
(v) Labour	7,70	-1,27

Table 7 Impact of drainage on income inequality in the Gohana area

Particulars	Control area	Project area	
		Before SSD (1995-96)	After SSD (1999-2000)
Gini Concentration Ratio (GCR)	0.18878	0.2263	0.0313

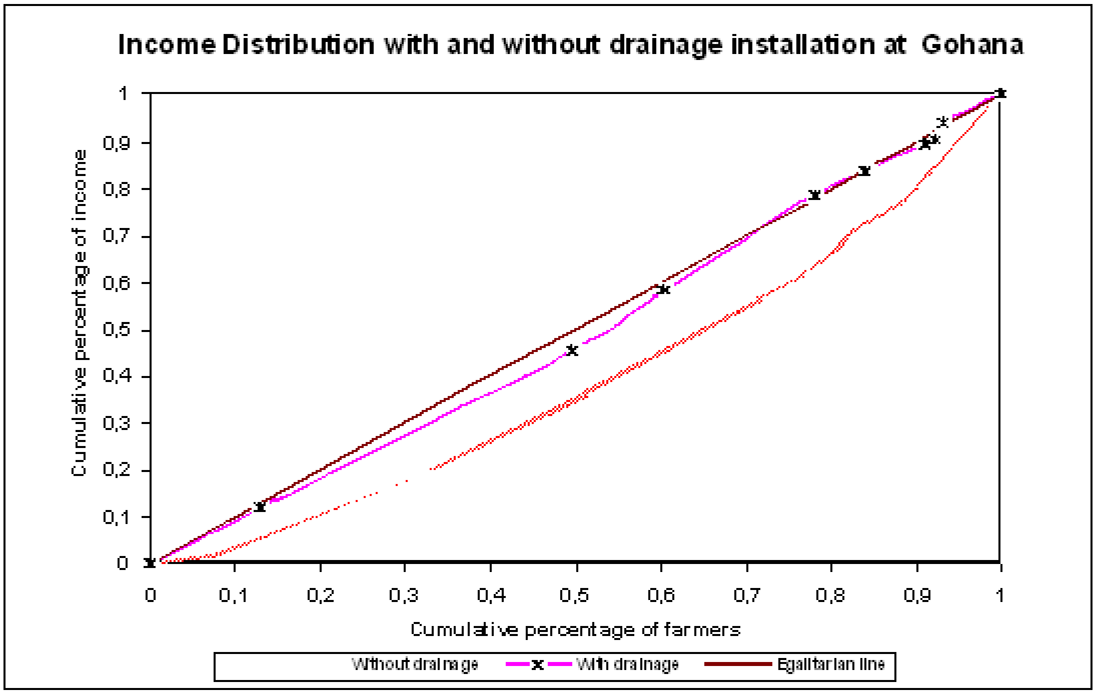

Figure 1

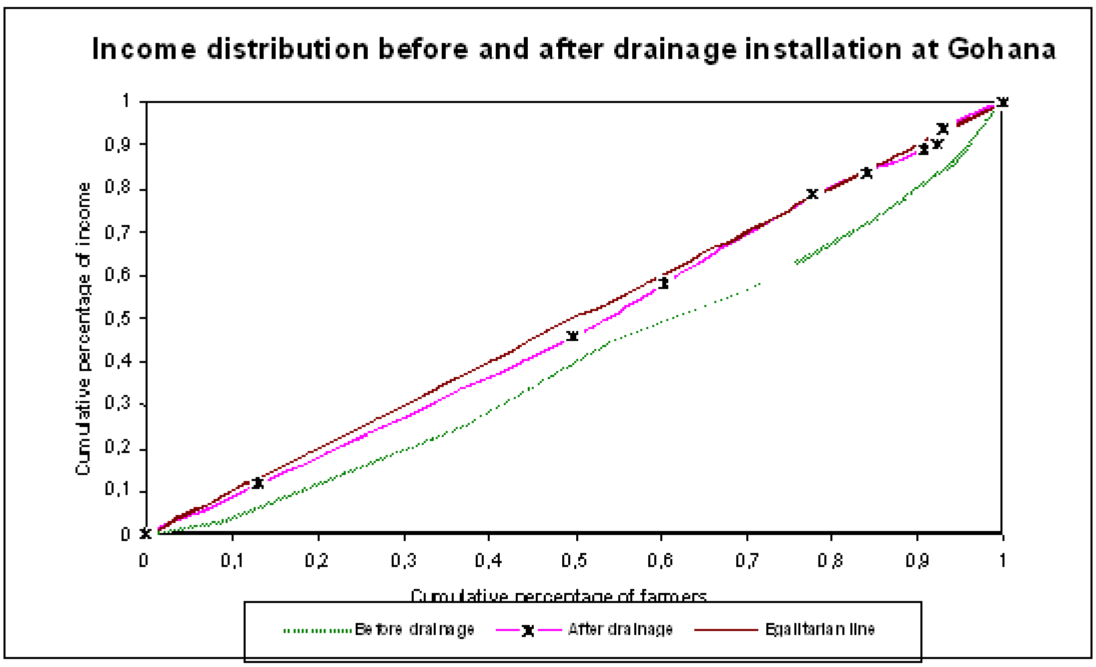

Figure 2

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[1] Paper No 115. Presented at the 9th International Drainage Workshop, September 10 – 13, 2003, Utrecht, The Netherlands.

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[3] International Institute for Land Reclamation and Improvement/ ILRI, The Netherlands.

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