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A Holistic Approach to Assess the Coets and Benefits of Modern Agriculture System in Punjab, India and Some Solutions

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Abstract Agriculture is a backbone of economy in the Indian state of Punjab where Green revolution was introduced early in 1960s and has contributed largely to make India self-sufficient in food production. Although, Green Revolution has enhanced food production and consequently the economic returns in agriculture sector, but it has many backlash effects. This study analyses the modern agriculture systems that were introduced with Green Revolution largely at the expense of over-and misuse of land and water resources and loss of biodiversity. It further evaluates the impact of changes in agricultural systems on the breakdown of socio cultural fabric. Rural people, particularly agricultural communities, are facing many serious problems including farmer's suicides, health problems such as cancer, loss of work culture among the youngsters, excessive use of alcohol and drugs and loss of cultural identity for people. Punjab, which used to be one of the progressive states in India, is suffering from the loss of natural, social and health capital. This study applies an integrated approach to assess the various costs and benefits of the current agricultural system in terms of well-being of people and of associated ecological and economic perspectives. It further suggests some innovative solutions for the current problems. A holistic approach applied in this study to assess the Green Revolution from socio-cultural, economic and ecological perspectives provides an in depth view of the problems that people are facing in so called economically developed state of Punjab in India.

Keywords: *green revolution, agriculture systems, socio-cultural, ecological and economic perspectives of agriculture, agricultural communities*

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1. Introduction

In developing countries such as India, agriculture not only contributes to the economy but also shapes the social fabric of the society. In the 1960s, with the onset of the Green Revolution (adoption of high-yielding cereal varieties, chemical inputs and mechanization), agricultural systems in developing countries have achieved remarkable improvements in crop production. Increased productivity in turn has fed millions who otherwise would have gone hungry. However, much of such improvements were based upon over-exploitation of natural resources [1-7].

During the initial phases of the Green Revolution, land area under cultivation increased along with cropping intensity and subsequently reliance upon chemical fertilizers and pesticides increased so as to maintain increased agricultural output (Figure 1), a common situation for many agricultural systems across the world. Tilman et al. [3] analysed the data on agricultural production and inputs at a global scale and questioned the sustainability of modern agricultural systems. Certainly, with new technologies, the Green Revolution has clearly led to enormous increases in agricultural output that in turn have supported the growing world population. However, with current levels of utilization of available area under cropping and maximization of chemical inputs, it seems unrealistic in the future to maintain the high level sofproduction [3].

About half of the global usable land is already under pastoral or intensive agriculture and many of the natural resources such as soil and water have been exploited to their maximum potential [3]. Increasing or even sustaining current levels of production while preventing degradation of available soil and water resources is a major challenge. Moreover the higher levels of external inputs of fertilizers and pesticides have degraded the natural as well as agro-ecosystems, leading to problems for changes in climate and natural environment.

1.1. Green Revolution in the Indian State of Punjab

The Green Revolution in India started in the state of Punjab in the late 1960s. After India's independence in 1947, there were two major consecutive drought events i.e., in 1964-65 and 1965-66 (apart from two unanticipated

wars with China and Pakistan in 1962 and 1965 respectively). Thus, provision and security of food for public was a major concern for the Indian Government at that time. Introduction of Green Revolution for agricultural development in Punjab was one main strategy under an Integrated Agricultural Districts Program (IADP) launched by the Indian government to overcome the food shortages. Punjab, with appropriate geographic location and availability of natural resources, was the premier state selected for the introduction of Green Revolution. This region was preferred due to the availability of rich alluvial soils and water from three main rivers, their tributaries and irrigation channels. Cultivation of wheat and rice were promoted mainly for their demand across the country as carbohydrate foods.

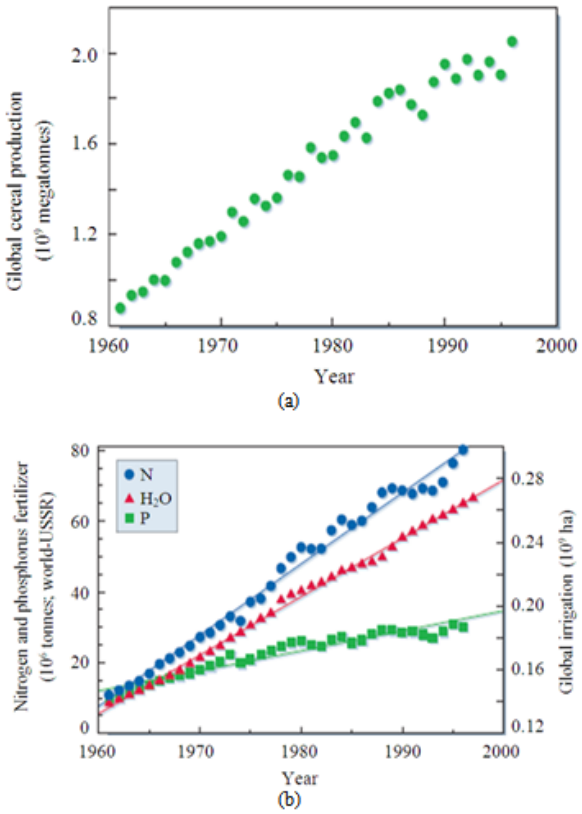

Figure 1. Agricultural trends over the past 40 years (Source: Tilman et al. [3]). (a) Total global cereal production; (b) Total global use of nitrogen and phosphorus fertilizers and area of global irrigated land

Since the introduction of Green Revolution, the state has contributed to produce mainly grain crops such as wheat and rice that made India sufficient in food production, thus called 'food bowl' of India. The state economy is mostly dependent on agriculture, so these advances in agriculture had led the state to be one of the economically advanced states in the country till 1980s. The state economy grew at a rate of 6 to 7% per annum during 1970-80s compared with 3 to 4% at national level and then it has slowed down to 3 to 4% per annum compared with 8 to 9% at the national level [4]. The main agricultural produce is wheat and rice that comprises about 85% of the gross value of total agricultural output and three-quarters of the total cropping area (with 90% irrigated area) in the state as reported by the International Food Policy Research Institute [7].

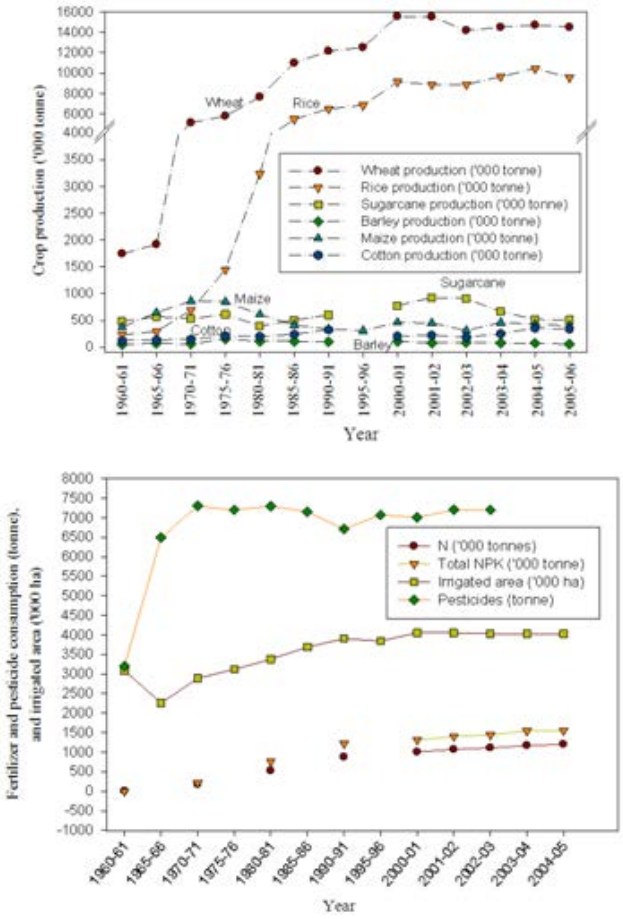

Figure 2. (a) Crop production, (b) Use of various inputs (fertilizers, pesticides and irrigated area) over time in agriculture, Punjab.Source: Statistical Abstracts of Punjab [8]).

With the introduction of Green Revolution in Punjab, the focus has been mainly on the production of wheat and rice that involves extensive use of soil and water resources and external inputs. Any associated environmental and/or social concerns due to decline in natural resources or external inputs have been broadly ignored for enhancing production and hence the economic returns. The economic returns from wheat and rice cultivation outweigh any other ecological, social and health concerns. Currently, after 50-60 years, the major focus of agricultural systems is still to achieve higher production outputs that may occur at any environmental or social cost which will be discussed in detail in this study.

The scenario that Tilman et al. [3] reported on a global scale as mentioned earlier, is well reflected in Punjab where production of wheat increased from 1,742,000 tons to 15,000,000 tons and of rice increased from 229,000 tons to about 9,000,000 tons from the early 1960s to the late 1990s and then stabilized over the last 7-10 years (Figure 2a), along with increased use of fertilizers and pesticides. The input of N and NPK fertilizers increased from '0' levels in 1960s to about 1000 tonne per hectare in 2004-06 and these estimates are conservative as the actual values will be much higher than reported in here (Figure 2b).

There is no doubt that Green Revolution steered the state to advance agricultural production and related economic gains, however this occurred at the cost of pollution and depletion of soil and water resources, decline in wild and crop plant diversity, loss of general

well-being and decline in public health and loss of cultural values (that includes loss of work-culture and excessive use of drugs among the youngsters); the costs of which largely remain unaccounted. Recently people have just started to realize the adverse effects in terms of health, environment and loss of traditional foods to some extent. The state has reached to the stage of stagnation where ecological, social and cultural costs could easily surpass the economic benefits from agricultural produce however such costs are largely outside the 'economic market' and remain 'untagged' and thus unaccounted.

The present study attempts to apply a holistic approach to address and analyze the various social, economic and ecological issues that are overlooked in lieu of production gains in the modern agricultural systems. This study evaluates the current situation and provides some innovative solutions to develop sustainable agricultural techniques which can offer multiple benefits to enhance well-being of agricultural communities that depend upon these systems for their livelihoods. Moreover, this study suggests 'lessons' from a premier Green Revolutionized State such as Punjab for providing a holistic analysis of the long-term benefits and losses of Green Revolution that will be valuable for other developing regions in the world that may be looking to implement such techniques in the future.

The main ecological, socio-cultural and health impacts of Green Revolution over the last 40-50 years are discussed below.

1.2. Ecological Concerns

The main ecological impacts of the current agriculture systems and related practices are:

1. Loss of soil productivity and pollution of soil resources
2. Pollution and depletion of water resources
3. Loss of crop and wild plant diversity

1.3. Loss of Soil Productivity and Pollution of Soil Resources

Continuous cultivation of wheat and rice over a large land area has resulted in nutrient run down in soils [9,10,11,12] have reported nitrate and phosphorus leaching and subsequent contamination of groundwater throughout the state. Consequently, the agricultural systems have become largely dependent upon chemical fertilizers (N, total NPK), inorganic herbicides and pesticides over time (Figure 2b) that has resulted in higher input costs and, therefore, a decline in the margin of profitability [13]. Most importantly, natural resources, i.e. soil and water, were taken as guaranteed and subsequently manipulated and used excessively to enhance agricultural production [1,9,14,15] to such an extent that recovery of these resources does not seem feasible in the near future.

Government of Punjab in 2009 [16] reported that pesticide usage has increased from 3200 kgha^{-1} of technical grade in 1980-81 to 5760 kgha^{-1} of technical grade in 2008-09, an increase of 44% in 30 years. These increases are related to higher levels of pest attack which are thought to relate to rises in humidity level in the recent years [17].

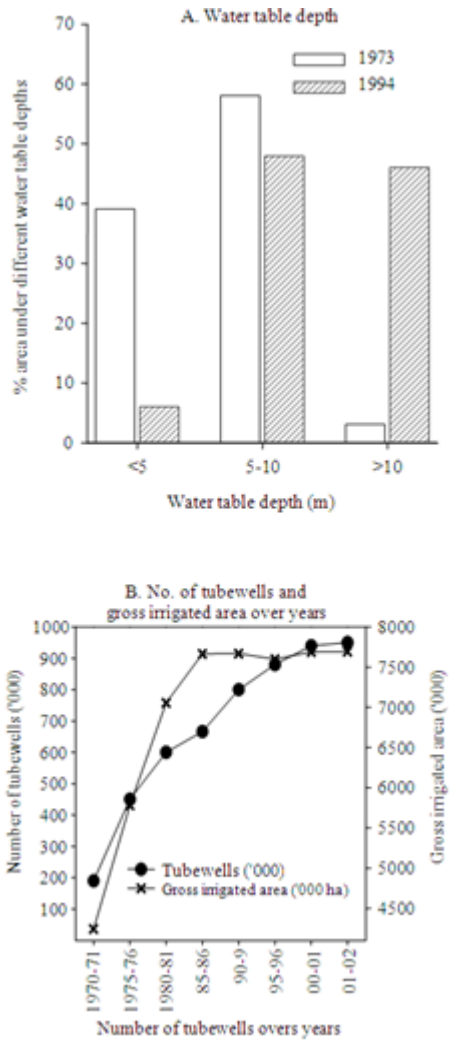

Figure 3. Water utilization: (A) Change in percentage of area under different water table depths from 1973 to 1994. (B)Increase in no. of tubewells and gross irrigated area over time.Data source: SAP [8].

1.4. Pollution and Depletion of Water Resources

Pollution of water resources mainly due to excessive use of fertilizers and pesticides and decline in availability of water for human use due to increase in cultivation area under irrigation throughout the state, are the alarming issues that have emerged due to current agricultural practices [15]. Aulakh et al. [18] conducted a state wide survey on water quality and highlighted the existence of dangerous levels of arsenic, selenium, lead and other minerals in soils and water that are hazardous to human health.The fall in water table in the state is usually attributed to increase in rice cultivation area from 1,180,000 ha in 1980-81 to 2,614,000 ha in 2003-04 [13]. The trends for rapid decline in the depth of the ground water table and increase in mining of water resources (water tubewells at every 2-5 km distance in the central zone) are of serious concern (Figure 3) [6].

Recent data collected by the Department of Agriculture (Government of Punjab) showed that despite having good rains in 2010, the water table across the state has further decreased [19]. The major rice growing areas in the central zone of Punjab registered a fall in the water table up to 1.75 m from June 2009 to June 2010 [19].

Singh and Sidhu [13] further suggested that the fall in water table has flow-on effects in terms of:

- The cost of pumping out water has increased, while the quality of water is getting poorer [20].
- Submersible pumps are replacing the centrifugal pumps, hence increasing the power use.
- Increase in the number of tubewells resulting in increased use of electricity. Consequently, the electricity is getting in short supply and diesel pumps are serving as a supplementary source of power are being increasingly used, accelerating the cost of production as well as increasing air pollution.
- In economic terms, there is an increase in cost by Rs 161/ha for wheat and Rs 573/ha for rice crop for the usage of water.

International Food Policy Research Institute [7] further reported that most districts in central Punjab exhibited severe overexploitation of water resources leading to risk of salinity. Salinity could be a serious problem for food production/security, not just for the state of Punjab but for all over India if it does occur in the current agricultural systems. There are examples in the past such as Harappan civilisation that faced the similar consequences of misuse of natural resources and of salinity causing the end of that civilisation; providing good lessons for the present generation.

1.5. Loss of Crop and Wild Plant Diversity

As more and more area has been brought under wheat and rice cultivation, the diversity of wild plants and other cultivated crops such as pulses and other cereals has decreased. Before the 1960-70s, people used to practice multi-cropping, with wheat, barley, maize, various pulses, cotton and the like (varied according to the region) to fulfill their own needs and to sell the rest of the crop for monetary gains. This system had helped the communities (both producers and consumers) to adapt to the climate and to the availability of natural resources to meet their needs, although there were less monetary benefits than from the present agricultural systems. This has changed drastically over the past half century and farmers largely became interested in agricultural output for economic gains [1]. Singh and Sidhu [13] reported that a number of crops like sun hemp, cluster beans and sorghum had almost disappeared and there is reduced varietal diversification in rice and wheat. With wheat-rice occupying more than 77% of net cropped area of Punjab [16], the crop diversification index has decreased from 0.75 in 1975-76 to 0.58 in 2006-07 [17].

Apart from the loss of minor crops, there has been significant loss of wild species where hardly any data is available. Some examples include disappearance of wild species such as Chenopodiumalbum, Commelina indica, which were widely used in famous winter dish ‘sarson ka sag’. Due to decrease in crop species diversity, there are greater incidents of diseases and insect-pests [17]. There is also a risk for the potential breakthrough of wheat and rice related diseases (such as rust/bacterial blight) that will be devastating for the state as its economy is mainly based upon agriculture. Due to loss of plant diversity and forest cover (which is only 6% (1382 square km) of the total area of the State), loss of fauna such as honey bees that play important role in agricultural systems and loss of common birds such as sparrows, peacockshas occurred at a fast speed (State of Environment, Punjab reports [21,22]). The situation is so worse that there are rare sightings of a famous bird-peacock (a national bird of India), of sparrows, crows and honey bees which used to be seen common about 20-30 years ago. Moreover, many natural honey producers (operating at a small commercial scale) have to travel to other states to find forested areas for their bees to enhance honey production. This possesses another challenge for cultivation of minor crops which may need the natural fauna for pollination. It could limit the capacity of the state to produce only wind-pollinated crops and could be a major backlash that has not been explored in any of the studies.

1.6. Socio-Cultural and Health Impacts

Each of the ecological impacts, mentioned above, has multiple repercussions on the social system that is closely linked to agriculture. During the course of the Green Revolution, the socio-economic fabric of agricultural society has changed remarkably in terms of social relations, cultural, health and economic values. The agricultural communities have changed from part subsistence-based agriculture (and part-commercial) to mostly commercialized agriculture. Moreover, the other rural communities in the state that indirectly depend upon agriculture, for example carpenter or lock and smith who used to make tools and help people in agriculture are badly affected. Such a situation is rather alarming when most of the population of the state relies upon agriculture not only for monetary gains but also for their basic living and other associated socio-cultural gains.

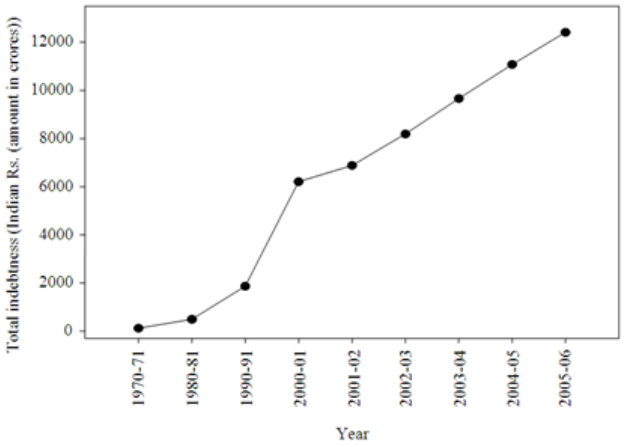

Figure 4. Total indebtedness of Punjab farmers over time(Source: SAP [8])

In terms of health impacts of current practices, pollution of soils due to excessive use of chemicals (fertilizers and pesticides) has exceeded above the permissible limits for human consumption in a large part of the state [19]. Some of the chemicals have entered the food chain (vegetables, fruits, milk) leading to many health problems. Aulakh et al. [18] highlighted the existence of dangerous levels of arsenic, selenium, lead and other minerals in soils and water that are hazardous to human health. Water availability and pollution have become another major health problem over the last decade, as a major study by the Central Ground Water Board revealed that ground water is polluted with chromium,

lead, manganese, iron, nitrate, selenium and arsenic, due to rampant use of fertilizers and increase in industrial effluents in most parts of the state (23 – The Tribune, 1/9/06). A recent study conducted by the Punjab Agricultural University (PAU) has indicated that ~ 80% of Punjab's groundwater is unfit for human consumption due to higher than permissible arsenic levels and suggested a link with rise in skin and lung cancer, especially in the six south-western districts of the state (18; 23 (The Tribune, 06/06/07)). Kaur and Sinha [24] provided a direct evidence of the effects of modern agriculture, particularly pollution of water and land resources, on human health. They reported increased incidents of cancer, mental retardation and kidney failures from various villages in the state in relation to changes in agricultural practices.

The other main social issues linked to current agricultural practices are financial burden, female foeticide, breakdown of social network, unemployment and meager career options leading to drug and alcohol addiction amongst youth. The landholding size has steadily decreased. About 800,000 farming families of the state have land holding of <5 ha, amongst which ~ 300,000 families have <0.5 ha of land [8]. The dependence for livelihood on such small landholdings has put 90% of the farmers of the state into debt (Figure 4; 23-The Tribune, 6/4/2007).

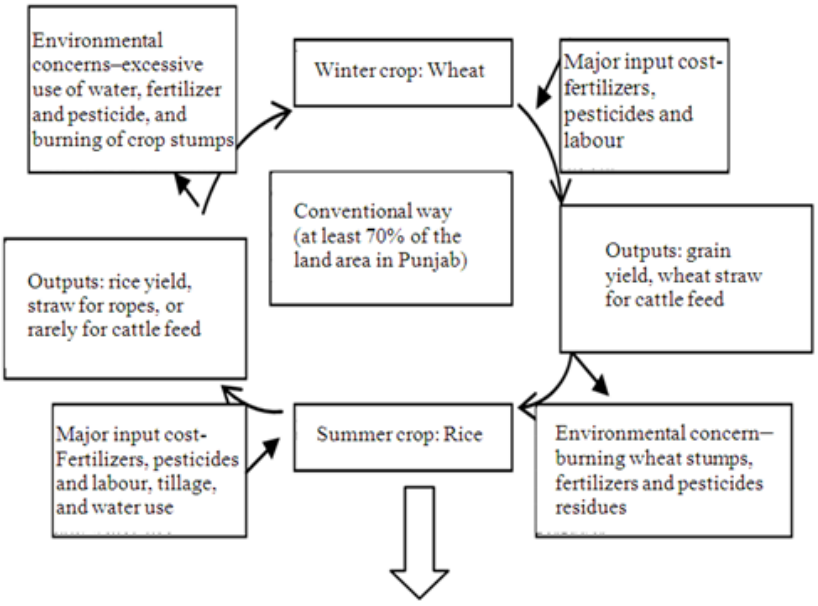

Figure 5. (a) Conventional cropping: wheat (sown in Oct-Nov and harvested in April) and rice (sown in June and harvested in Sept-Oct)and (b) Proposed ST system (based upon scientific and traditional knowledge, suitable summer crop can be selected after consulting (a) Socio-economic and health benefits, Mainly economic gains (unsustainable) Reduced social, natural and health capital, (b) Socio-economic and health benefits, Economic viability with sustainable gains Gains in Socio-cultural, natural and health capital

The average annual loan for Punjab farmers is Rs. 40,000, which is three times higher than the average amount of a loan for an average Indian farmer (23- The Tribune, 3/4/06). The recent statistical data for 2010 may indicate further increased levels of debt, which is still unavailable.

The higher amount of debt is mainly due to increased input costs for agriculture and in part to meet the socio-economic standards that have been established with increases in income in the past. This has resulted into an unacceptable social situation as exemplified by the increase in farmers' suicides across the state. There are approximately 40,000 unofficial suicidal records between 1998-2005 (23- The Tribune, 3/4/06). A main concern of the present agricultural systems is that despite all the human efforts and maximum inputs, profitability of agricultural systems has declined over time [1,25].

Most of these ecological and social problems have been earlier highlighted in isolation from each other [1,18,21,22, 25,26,27]. However, little effort has been directed to view the holistic perspective and to resolve the problems. Use of resources in a sustainable manner that ensures well-being of rural communities while considering socio-economic, cultural and health perspectives could provide a way to resolve the current situation and to move forward to improve the system for future generations. There is also a need provide a new vision for agricultural communities to enhance their perceptions of agriculture beyond the financial returns that includes non-monetary benefits of agricultural systems such as work-culture, good health, cultural, identity and moral values, so that they view the improvements in agricultural systems in a holistic way.

How to develop and sustain agricultural systems that enhance socio-economic and ecological well-being of agriculture dependent communities?

With >80% of the land area under cultivation (and ~100% irrigation of cropping land [8]) and at maximum levels of inputs, there is a limited scope to enhance or to sustain crop yield based upon current level of utilization of available land and inputs. Therefore, a major concern is how to sustain the agricultural output to sustainably meet the needs of the growing population?

This study suggests some innovative crop technologies that can help improve the well-being of agricultural societies and will suggests changes in the current practices for the efficient use of natural resources. A model (Figure 5) is suggested that aims to conserve soil and water resources, to reduce agricultural inputs and increase biodiversity of agricultural landscapes. The conventional cropping system involves wheat and rice cultivation over a year, with intensive labor, mechanical and chemical input (Figure 5a). The proposed model aims to diversify the current pattern by selecting suitable alternative crops to rice that could lead to sustainable agricultural production along with other ecological and socio-economic benefits.

This will include application of sustainable agricultural practices that help to manage soil and water resources such as organic manure, efficient use of water and fertilizers, maintaining stubble for decomposition, promoting work culture among the youngsters, sharing of resources (machinery) and creating local markets in the community for consumption of products from the proposed crop model which is based upon Scientific and Traditional (ST) knowledge systems.

1.7. Approach (Design and Methods)

An integrated approach (as suggested in Figure 5, based upon scientific and traditional knowledge) that helps to sustain the natural resources while satisfying human needs, is a doable alternative approach to the current practices of cultivation. There are three main agro-ecological regions in Punjab (Table 1) and crops should be promoted according to the geography of a region. PAU has set up regional centres throughout the state (KVK- Krishi Vigyan Kendras (agriculture science centres for farmers), which are responsible to deliver the new research outcomes to the farmers and also to execute research onsite. These centres can play a significant role in proposing and promoting the changes but unfortunately very little has been achieved in the recent years since we started facing the backlash of modern agricultural systems.

2. Discussion

Sustainability of agricultural systems is a worldwide issue [3]. Monoculture is a major outcome of the Green Revolution aimed at maximizing production. However, very little research links its outcomes to the ecological and socio-economic implications. Implementing new crop technologies for sustainable agriculture and linking their role to human well-being in this study attempts to provide a holistic perspective to improve the overall ecosystem that includes people and their agricultural and natural environment.

There is no doubt that wheat and rice crops provide the maximum financial returns [17], but this is mainly because of the reliable markets, support prices for these crops and due to unaccountability of use of water and land resources. The high value crops such as Black gram (Cicer arietinum and related species), Mung beans (Phaseolus aureus and related species) (alternative to rice) suggested for crop diversification in here have no reliable market [4,28]. Shergill [29] argued that wheat-rice specialization has a sound economic footing under the current parameters and constraints in terms of food security, however this study argues that such a system is not ecologically viable and can't sustain over a long term. Moreover, the associated costs for decline in human health, social and cultural values need to be incorporated in such an analysis. Any economic analysis of agricultural systems without the inclusion the associated ecological, socio-cultural and health benefits/costs is incomplete as agricultural communities depend upon these systems for their well-being.

IFPRI [7] reported that subsidies for fertilizers, pesticides, irrigation and electric power are the major contributors to the continuum of wheat-rice cycle, which is degrading the natural resources and overall ecological system of the state. Subsidies had been promoted by the Indian government to enhance food production and food security, however now farmers are facing the consequences in terms of depleting and polluting their own land and water resources which are without any price tag. The subsidies are also contributing to discouragement of diversification of crops because of budgetary support from higher return investment such as wheat and rice [7]. The potential risk of soil salinity as IFPRI [7] reported is

of serious concern for the producers as well for consumers. If Punjab cannot produce enough food grains then the whole country can suffer due to shortage of food; a consequence of badly managing natural resources.

There is a wrong perception about the high levels of financial gains in wheat-rice cropping system that suggests Punjab agriculture is viable. This is mainly because there is no price tag for the excessive use and pollution of water and land resources and for the cost of household efforts in agriculture. Moreover, there is no cost measures to include the cost of various health and cultural issues, particularly for the young generation getting trapped in drug usage.

Recently, the intensity of farming and in particular, the use of pesticides, fertilisers and water has led to serious concerns about the economic sustainability of farming systems. Sidhu et al. [17,25] suggested that increases in the cost of production for wheat-rice cropping are decreasing the margin of profitability, thus making the agricultural systems less sustainable. The use of natural resource for agricultural production in Punjab is in contrast to that in many developed countries such as Australia where farmers have to pay for their share of water usage and have to pay penalties for polluting water or land resources, mainly due to the existence of regulation and monitoring procedures implied by the Environmental departments in various states. In Punjab, there is no application of such legal procedures that may save and guard water and land resources from over-exploitation and pollution. This is the main reason that water levels are now depleted to such drastic levels over the past 30-40 years that availability of safe water for drinking has become a major issue now a days. But, still there are no control measures in place to regulate the use of this precious resource. The free rider effect of use of water and soil resources and above that pollution of these resources due to excessive use of pesticides and fertilizers without any regulation/ control measures, have largely resulted in vast scale degradation of natural resources and weakening of the socio-cultural system including well-being of agricultural and other rural communities. The major flaw in the current agriculture is that these systems are largely evaluated on the basis of production or financial returns without considering the cost of loss of ecological services that contribute in production, or loss of social-cultural values or the cost of associated health issues. If we include the costs for loss of social values, loss of work-culture among the youngsters and abuse of drugs and alcohol and others, then the total costs that the state has paid for Green Revolution are much greater than any improvements in the current agricultural systems. Moreover, the natural resources are so depleted that it does not seem possible to retrieve these to their original states in any near future.

It has been suggested [28] that Punjab's agricultural production system could be successfully replicated in other parts of the country or world like Sub-Saharan Africa. However, we need to be careful for such level of execution without evaluating the overall impact of Green Revolution and its practices that includes socio-economic and cultural perspectives too, as discussed in here. There are many lessons that could be learnt from the Green Revolution experiment in the state of Punjab, particularly the associated social, cultural and health costs.

The present paper provides a holisitic perspective of various socio-cultural and ecological problems that are currently occurring in Punjab mainly due to modern agricultural practices. It can provide useful information to develop sustainable systems for agriculture in this and other parts of the world by learning about suitable crops, practices and will help to understand the cost of foregone ecological functions and other socio-cultural values in terms of their role in agricultural output and well-being of people. It suggests to develop sustainable farming systems that include selecting appropriate crops based on their climatic suitability, productivity and resource use efficiency and practices that enhance the potential of soil for various ecological functions. This study highlights the links between farming systems and well-being of people (socio-economic); thus helping to evaluate the role of farming systems in terms of socio-economics of agricultural communities. Moreover, by exploring the linkages between ecologically sustainable agricultural systems and human well-being (socio-economic), the paper projects a holistic picture of modern agricultural practices which can help to develop sustainable societies in the future.

An eminent agricultural scientist in India, Prof. S. S. Johl has rightly said "Forget green revolution, in the present situation Punjab is only heading towards brown revolution – it can turn into a desert." adding that the state is paying a heavy price for being the cradle of first green revolution [23]. This study calls for an urgent need to work collectively not just to improve the agricultural systems but to save the social, natural and cultural capital so that agricultural and other rural communities as well as their natural systems can sustain over a long term.

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