

Irrigation Expansion and Groundwater Fluctuation in Punjab Satluj Floodplain, India: A Causal Analysis from 1971 to 2012

Harsimrat Kaur Gill

Assistant Professor, Geography Department, Post Graduate Government College Sector 46, Chandigarh
gkharsimrat@gmail.com

Abstract- A large area of Punjab Satluj floodplain is cover under agricultural land. Agriculture sector is known to be a high water consumption venture that depends upon irrigation. Groundwater is one of the prominent sources of irrigation in Punjab with rivers and canals. With time agriculture expanded in this area along with other allied activities. The net irrigated area was 33568.04 hectares (32.19%) in 1971 that increased to 65030 hectares (62.36%) in 1981, 77193 hectares (74.02%) in 1991, 89588 hectares (85.91%) in 2001 and 91432.47 hectares (87.68%) in 2011. This process adversely affects the groundwater condition, as the major source of irrigation in this area is tube wells. In 1960 there were 574 well/tube wells; which increased to 4212 during 2011 with 32 water tanks. Utilization of these modes of irrigation resulted in increased groundwater depth from surface level. In 1972 pre-monsoon ground water depth ranged between 1 and 12.33 meters and the post monsoon figures ranged between 1 and 12 meters, in 2012 these figures had increased to 2.75 to 33.47 meters in pre monsoon and 2.85 to 33.29 meters in post monsoon period. It is obvious that the rate of discharge exceeds the rate of recharge through monsoonal rain. This situation was observed in the maximum part of Punjab Satluj floodplain and raised the concern for sustainable groundwater utilization.

Index Terms- Agriculture; Irrigation; Ground water depletion; Floodplain; Groundwater discharge.

1. INTRODUCTION

Punjab experienced land use expansion over land cover with the successful execution of Green Revolution. This can be noticed from the increased Gross Cropped Area, which was 5678 thousand hectares during 1970-71 and reached to 7882 thousand hectares in 2010-11 [1]. This enormous increase took place at the expense of natural cover [2]. Punjab State is attributed with unique type of terrain in the form of floodplains that covers it's one sixth part [3]. Satluj floodplain is one of them with fertile soil and ample water that promote agricultural expansion and intensification. It can be relate with the increased percentage of net irrigated land over net cultivated area that accounted 71.25% in 1970-71 and increased to 97.88% during 2010-11. This intern increased the pressure on water resources. Dependency on canal irrigation systems were the first preference till 1990-91 [4]. Since 1990-91 tube wells and wells irrigated area increased. This was possible with loans extended by State Land Development Bank for tube well installation and liberal electrification of tube wells [5], [6], [7]. The number of tube wells in the study area increased from 574 in 1960 to 4212 in 2011. As a

result the area served per well/tube well decreased from 63.17 hectares in 1955 to 8.61 hectares in 2011 [8]. Alongside this net cultivated land increased from 36.25 thousand hectares to 91.01 thousands hectares during 1955-2011 and the net irrigated area increased from 33.56 thousand hectares in 1971 to 91.43 thousand hectares in 2011. Ground water extraction for irrigation through wells and tube wells increased the ground water depth of this area which challenges the recharge capacity of the monsoonal rainfall.

2. STUDY AREA

Punjab Satluj Floodplain is spread between 30°32' N to 31°35' N and 75°05' E to 76°44' E latitudes and longitudes respectively and covers 104275.1 hectares. This natural entity overlapped by the parts of Phillaur Block of Jalandhar district, Aur, Nawanshahr and Balachaur block of Shahid Bhagat Singh Nagar district, Chamkaur Sahib Block of Rupnagar district and Machhiwara, Ludhiana II and Ludhiana I block of Ludhiana district of Punjab State of India (figure 1).

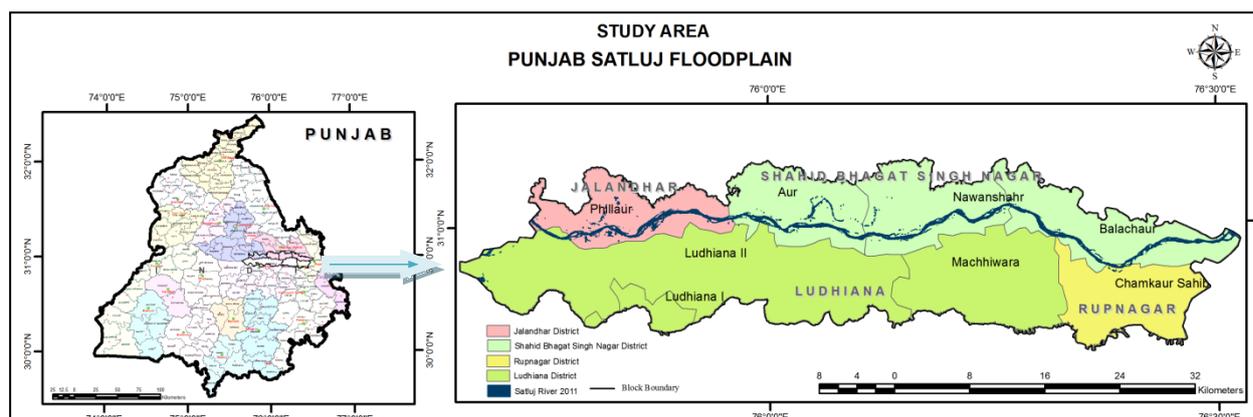


Figure 1: Punjab Satluj Floodplain

3. MATERIAL AND METHODS

Ground water quantity has been analyzed for estimating the impact of expanded agricultural practices. Two data sets have been prepared one for explaining the agricultural expansion and other for estimating the ground water depth. Agricultural data of 478 villages of study area has been collected from Census of India Handbooks. Ground water depth data has been collected from the Department of Soil and Conservation, Punjab and Central Groundwater Board, India. Ground water depth has been estimated from the identified fifty wells for June and October months of 1972 and 2012 for analyzing seasonal fluctuations. Spatial plotting of groundwater data has been drawn in Geographic Information System by using spline interpolation technique. For analyzing the impact of cropped area on groundwater, layers generated through choropleth technique were overlapped over isobath maps.

4. RESULTS

Expanded irrigated cultivation over cropped area exerts pressure on water resources [9]. In Punjab Satluj floodplain both net cropped area as well as net irrigated area had been doubled since 1970's. Change in net irrigated land in this area reflects agricultural intensification, which adversely affects the groundwater regime of this area. With time maximum places faced fall in water table due to excessive groundwater use and some areas experienced rise in water table due to excessive irrigation. During 1972, underground water depth from surface level for pre monsoon season ranged between 1 to 12.33 meters and it reduced to 1 to 12 meters for post monsoon season. This reduction rate indicates the recharging of ground water table from monsoonal rain. During this time 46146 hectares area was net cultivated, which covered 44.25% of total study area. Its 56.9% villages were practicing extensive cultivation as their 75.01 to 100% area was net cultivated (table 1). Area

characterized with high ground water depth to surface level ranged between 12 to 14 meters below ground level during pre-monsoon period was observed in areas adjoining the river bluff consisting north eastern part of Balachaur Block of Shahid Bhagat Singh District, southern part of Balachaur Block (Shahid Bhagat Singh District), north western part of Chamkaur Sahib block (Rupnagar District) and north eastern part of Machhiwara Block (Ludhiana District), south eastern part of Machhiwara Block of Ludhiana District, central part of Nawanshahr Block of Shahid Bhagat Singh District, north western and central part of Ludhiana II Block of Ludhiana District and Phillaur Block of Jalandhar District (figure 2 (a)). Maximum area with this underground water depth was covered with those villages that consisting 50.01 to 100% net cultivated land. Post monsoon ground water depth variability depicts that maximum ground water depth was reduced and highest range was 10 to 12 meters. This highest range was observed in those areas, which experienced 12 to 14 meters ground water depth during pre-monsoon period (figure 2 (a)). In 2011, human exerted pressure on groundwater in the form of agricultural activities was increased as 86% villages were practicing agriculture on their 75.01 to 100% area. During this period 88.75% of Satluj floodplain area was net cultivated (table 1).

That resulted in the increased groundwater depth for 2012; it was 2.75 to 33.47 meters during pre-monsoon period and 2.85 to 33.29 meters for post monsoon season. Areas earlier under 12 to 14 meters ground water depth was intensively used for ground water extraction and during this period it was transferred to higher category i.e. above 16 meters groundwater depth below surface. This shows the pressure exertion of agricultural activities on groundwater as it transit from extensive expansion to intensive expansion. Area characterized with high groundwater depth covered center of the Balachaur Block (Shahid Bhagat Singh District), north western part of Chamkaur Sahib Block (Rupnagar District) and north eastern portion of

Machhiwara Block (Ludhiana District). 14 to 16 meters ground water depth category also covered the south eastern part of Machhiwara Block of Ludhiana District. This range was also observed in the central part of Nawanshahr Block of Shahid Bhagat Singh District. Central portion of Ludhiana District was also incorporated in this maximum ground water depth range. This high range was also observed in south western part of Phillaur Block of Jalandhar District and north western part of Ludhiana II Block of Ludhiana District (figure 2 (b)).

Table 1: Net Cultivated Land and Groundwater Depth in Punjab Satluj Floodplain: A Comparative Trend Analysis for 1971 and 2012

Year	Net Cultivated Land (in Hectares)	Number of Villages with 75.01-100% Net Cultivated Area	Affected (Pre-Monsoon) Groundwater Depth (in meters)	Recharged (Post Monsoon) Groundwater Depth (in meters)
1971-72	46146 (44.25%)	268 (56.9%)	1 - 12.33	1 - 12
2011-12	92550.47 (88.75%)	405 (86.35%)	2.75 - 33.47	2.85 - 33.29

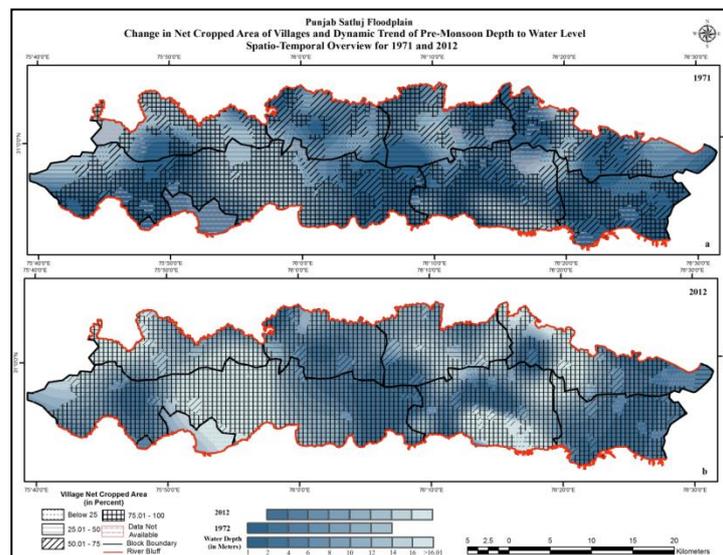
Parentheses values represents percentage calculated from Satluj floodplain area for net cultivated land and percentage obtained from total number of villages covered in study area for villages with 75.01-100% net cultivated area.

Source: Census of India, 1971 and 2011 and Central Groundwater Board, India.

Ground water depth was increased with time due to intensive extraction of groundwater through tubewells. During **1970-1980**, increase in net irrigated land was 31461.95 hectares and groundwater level fluctuation ranged between -0.9 to 11.05 meters for Satluj floodplain. Fall in water table was observed in north eastward and south westward part of the floodplain (figure 3 (a)). Areas observed maximum fall with 10 to 12 meters in water level during this decade included central and north western part of the Balachaur Block of the Shahid Bhagat Singh Nagar District. During this time 0.1 to 0.9 meters rise in water table was observed in parts of Balachaur Block (Shahid Bhagat Singh Nagar District) and Chamkaur Sahib Block (Rupnagar District). For **2000-2012**, change in groundwater level was ranged between -1.9 to 18.29 meters and maximum fall in water level with 12 to 18.29 meters was observed in the south central part of Machhiwara Block of Ludhiana District (figure 3 (b)). During this period net irrigated area was expanded over 91432.47 hectares land. Rise in water table with 0 to 1.9 meters was noticed in eastern and central part of the floodplain area (figure 3 (b)). Rise in water level can affect the soil fertility as rise in water level positively

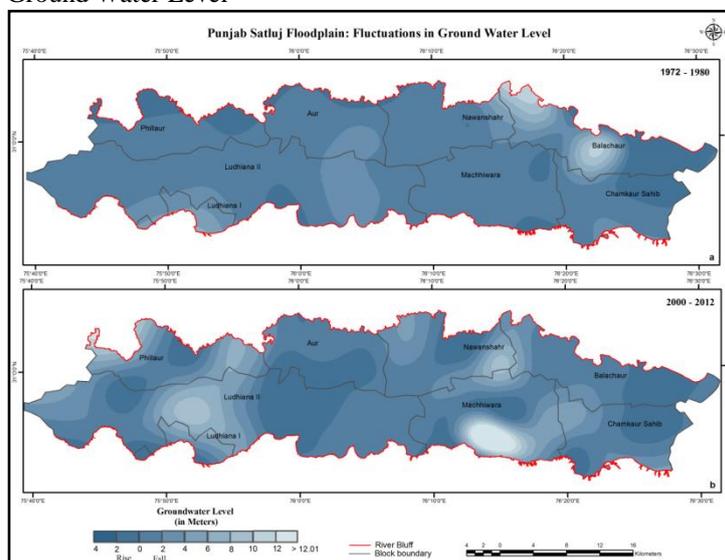
affects the salt balance of soil [10], which leads to the salinization and degrade the quality of land.

Figure 2: Punjab Satluj Floodplain: Net Cropped Area and Groundwater Depth: Causal Relationship



Source: Census of India, 1971 and 2011 and Central Groundwater Board, India

Figure 3: Punjab Satluj Floodplain: Fluctuations in Ground Water Level



Source: Central Groundwater Board, India

5. DISCUSSION

Human tendency to exploit natural resources for their benefit is turning high with technological advancement and this trigger the deterioration rate of environmental health. Basic needs of human genera i.e. food, cloth and shelter can be possible through the expansion of land use activities. Tremendous increase in land use activities had been noticed in this spatial

unit as it favored fertile alluvial soil and ample surface and sub surface water. Research findings show that:

- Human number in this area was 615423 during 1971 that increased to 2198128 in 2011. For fulfilling the food demand of this increased human number promotion of agricultural sector had been done, which can be well estimated from the 93.41% agricultural increase that took place in 36 years i.e. from 1975 to 2011. This expansion resulted in the loss of natural cover.
- This tremendous rate of increase in human number and their demands necessitates the intensive use of land. That cannot be possible through rainfed agricultural practices, so in this area different modes of irrigation such as canals, wells and tube wells had been promoted that resulted in 172.38% increase in net irrigated land from 1975 to 2011.
- Cheap and easy accessible groundwater through tube wells increased the dependency of farmers on this mode of irrigation. Continuous mining of groundwater resulted in lowering of water table in this area. Groundwater depletion can be estimated from the increased range of groundwater depth from the surface level that observed during 1972 to 2012. In 1972 groundwater range between 1 and 12 meters below surface level that has been increased to 2.75 to 33.47 meters for 2012.
- 87.68% area of Punjab Satluj floodplain covered under net irrigated land. That high existence of net irrigated area and rate of groundwater depletion raised the question of sustainability with reference to groundwater utilization and human habitation in this flood prone area.

6. CONCLUSION

Water is a primary attraction that floodplain offers to human occupation. Change in irrigation pattern left an impact on the availability, quantity and quality of water. During 1970 in Punjab Satluj floodplain 32.19% area was net irrigated and in 2011 this has been increased to 87.68%. This depletes 16.47% surface water from 1955 to 2011 and increase the ground water depth of this area. In 1970 the pre-monsoon ground water depth ranged between 1 and 12.33 meters and the post monsoon figures ranged between 1 and 12 meters, in 2012 these figures had increased to 2.75 to 33.47 meters in pre monsoon and 2.85 to 33.29 meters in post monsoon period. It is obvious that the rate of discharge exceeds the rate of recharge through monsoonal rain. This was the situation in most of the floodplains. However there

were some parts that depicted a rise in ground water table due to excessive irrigation.

Adverse implications of agricultural intensification in Punjab Satluj floodplain can be estimated from the depleted surface and sub surface water, which was once inherently enriched in this resource as per physical location of River Satluj.

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