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Environmental Issues, Economic Policies and Agricultural Development: The Case of Punjab, India

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Abstract

This paper discusses economic policies that have supported a particular kind of agricultural development in Punjab, as well as environment-specific policies, that have sought to deal with various environmental problems arising from that pattern of development. In doing so, we highlight some major environmental issues associated with economic policies in the state, including with respect to water, air, soil and climate change. We analyse why and how economic policy failures, including at the national level, adversely affect environmental quality in Punjab. The aim of this paper is to highlight these issues, as a first step towards identifying policies that may do a better job of protecting the environment.

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I. Introduction

Generally, economic policies that help eliminate market distortions can stimulate growth and potentially also improve environmental quality. However, when economic policies fail to create appropriate environmental incentives, or when environment-specific policies fail to correct market failures, these policy shortcomings can contribute significantly to many environmental problems. This paper investigates how economic policies affect environmental quality, using the Indian state of Punjab as a case study.

Punjab, in north-western India, has been one of the richest states in India. It occupies only about 1.54% of the total area of India but produces a relatively high proportion of the national food output, especially when measured by contributions to the Public Distribution System (PDS) for wheat and rice. The PDS has been a vital part of national food policy, for providing the country's poor with access to affordable minimum quantities of foodgrains. Punjab has also been a trendsetter for much of the rest of India in terms of farm practices and policies.

Punjab has a long history of agricultural success, rooted in its natural resources, specifically, its fertile river plains. In the 1960s, Punjab was selected by the Indian government to be the first place to try new hybrid varieties of wheat (and later rice), partly because of its water resources and infrastructure, and partly for other reasons rooted in market access and political economy. The increase in yields and output that resulted from this policy came to be called the Green Revolution. Punjab's largest crop remains wheat, and it produces 20% of India's wheat (2% of the world's wheat) and 9% of India's rice (1% of the world's rice) (K. Yadav, 2013).

To support the expansion of agriculture in Punjab, especially as geared toward supplying the PDS, the government introduced policies for improving access to fertilizers, tractors, and (especially) water, in many cases building infrastructure and providing subsidies. Access to markets and price guarantees have also been an important part of this system. It should not be surprising that Punjab has done remarkably well in agriculture, and the economy of Punjab has continued to depend relatively heavily on that sector. However, the rapid growth of agricultural production in the pattern the state has followed has arguably put tremendous pressure on the state's natural resources and contributed to severe environmental issues in the state. In turn, those environmental problems may have negatively affected not just agricultural development, but also impeded overall economic development in Punjab.

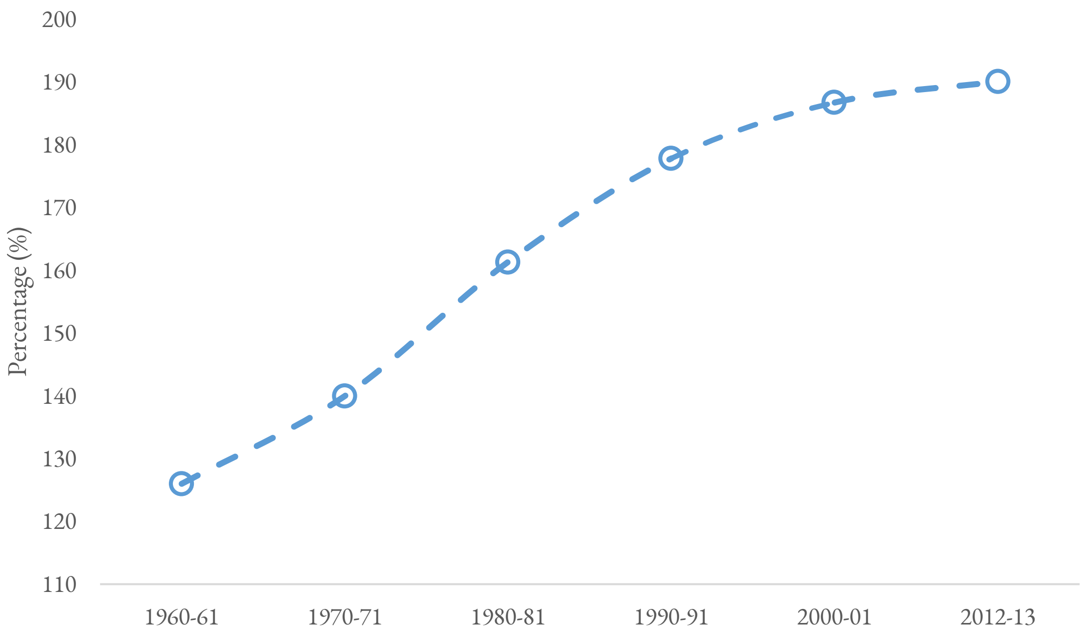
In the following sections, we discuss economic policies formulated to support agricultural development in Punjab, as well as environment-specific policies meant to deal with various environmental problems that have arisen. We highlight some major environmental issues associated with economic policies in the state. Importantly, we analyse why and how economic policy failures adversely affect environmental quality in Punjab. The aim of this paper is to highlight these issues, as a first step towards identifying policies that may do a better job of protecting the environment. While Punjab is a relatively small state in a large country, it can serve as a useful case study for other parts of India, as well as regions elsewhere in the world.

II. Background

Like many regions in developing countries, the state of Punjab in India is experiencing serious environmental problems. Population expansion and growth of agricultural production have put pressure on local natural resources and exacerbated levels of pollution. The nature of Punjab's environmental problems is mostly associated with its pattern of agricultural development, rather than the state's limited industrialization. This pattern was the result of the national government's decision to introduce high-yielding varieties of wheat and later paddy (rice) as a way of achieving domestic food security: the Green Revolution.

Public procurement of these crops at guaranteed minimum prices provided an income floor and risk mitigation, encouraging adoption, and later discouraging switching to other crops. Village electrification in Punjab was achieved earlier than in other parts of India, and, as canal irrigation failed to keep up with demand for water, farmers increasingly turned to pumping groundwater for irrigation, which created pressures for subsidized or even free electricity and water for farmers. The development of this particular pattern of intensive agricultural practices has negatively affected the environment in Punjab over recent decades. In this region, about 83% of land is under agricultural cultivation and cropping intensity (crops per year) increased sharply, from 126% in 1960-1961 to 191% in 2012-2013, with the adoption of input-intensive agricultural practices (Figure 1).

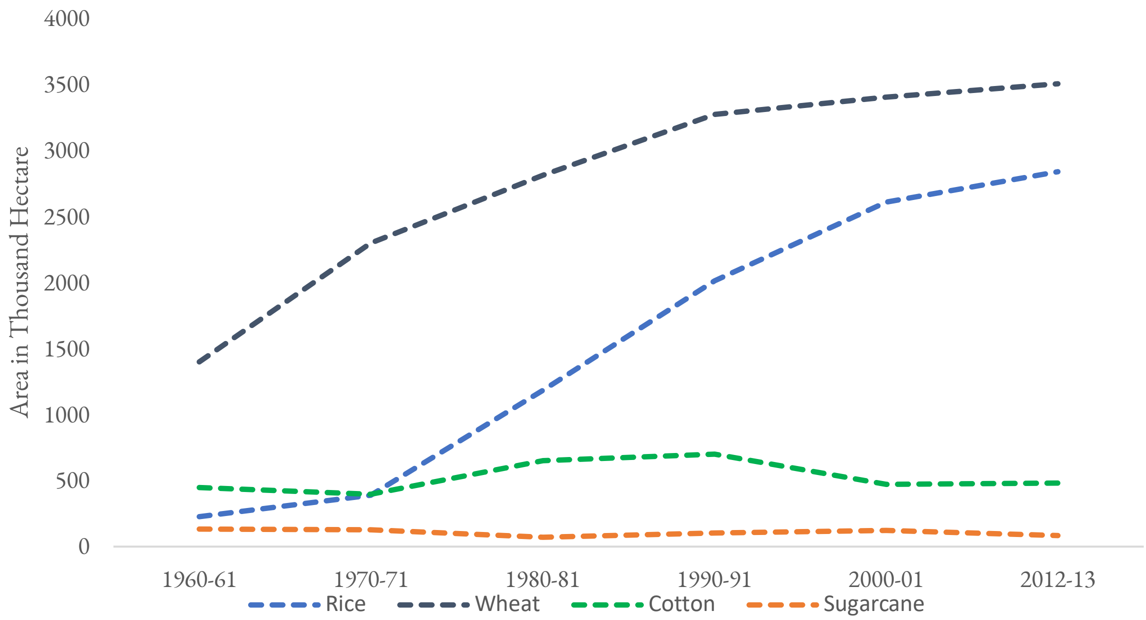
Figure 1: Cropping Intensity in Punjab



Source: Department of Agriculture, Punjab, 2013

This cropping pattern has been based on paddy-wheat dominance[1] since the Green Revolution and has arguably created many environmental issues in Punjab. It has harmed biodiversity and resulted in land degradation, soil nutrition depletion, a plummeting groundwater table, and pollution from heavy fertilizer and pesticide usage. Despite the fact that wheat and rice are crops with lower value-added compared with other options, the effective "monoculture" of wheat and rice grown in lockstep has not seen a significant decrease in recent years (Figure 2).

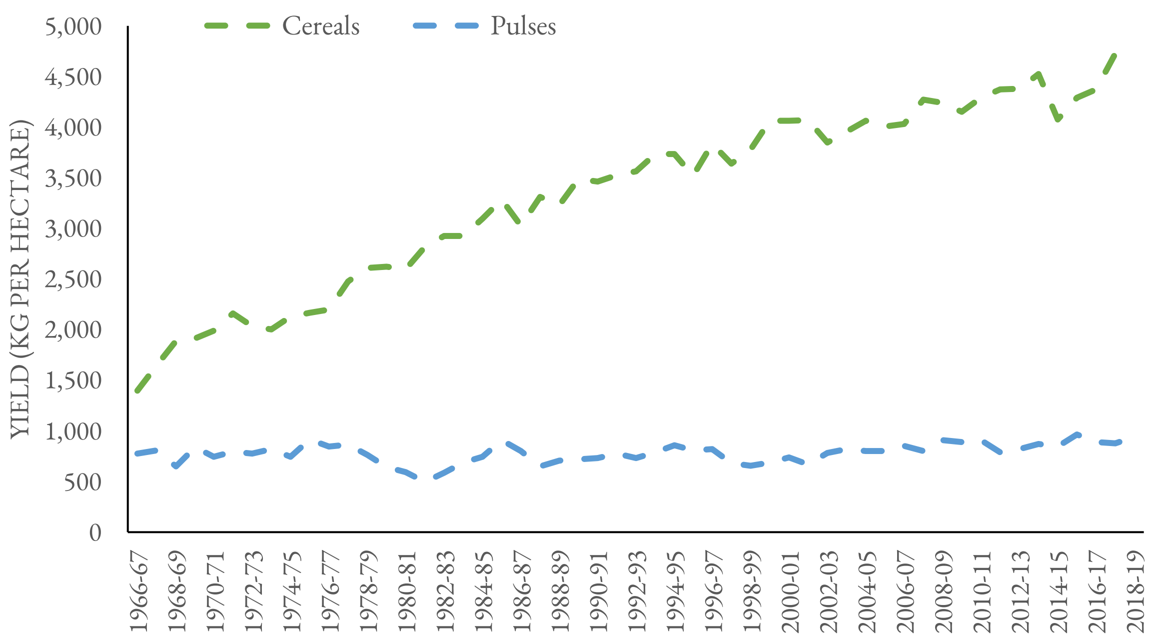
Figure 2: Showing the area under cultivation of different crops in Punjab



Source: Department of Agriculture, Punjab, 2013

Increases in the cultivated area and cropping intensity of wheat and rice have been associated with increased yields. This is evident in Figure 3, where the upward trend in the yield of cereals (chiefly wheat and paddy) is significant. By contrast, the yield for pulses has barely increased, and does not exhibit a steady trend. A statistical test for an endogenously determined structural break in the cereal yield series reveals a break in 1994-95.[2]

Figure 3: Yield of Cereals and Pulses in Punjab

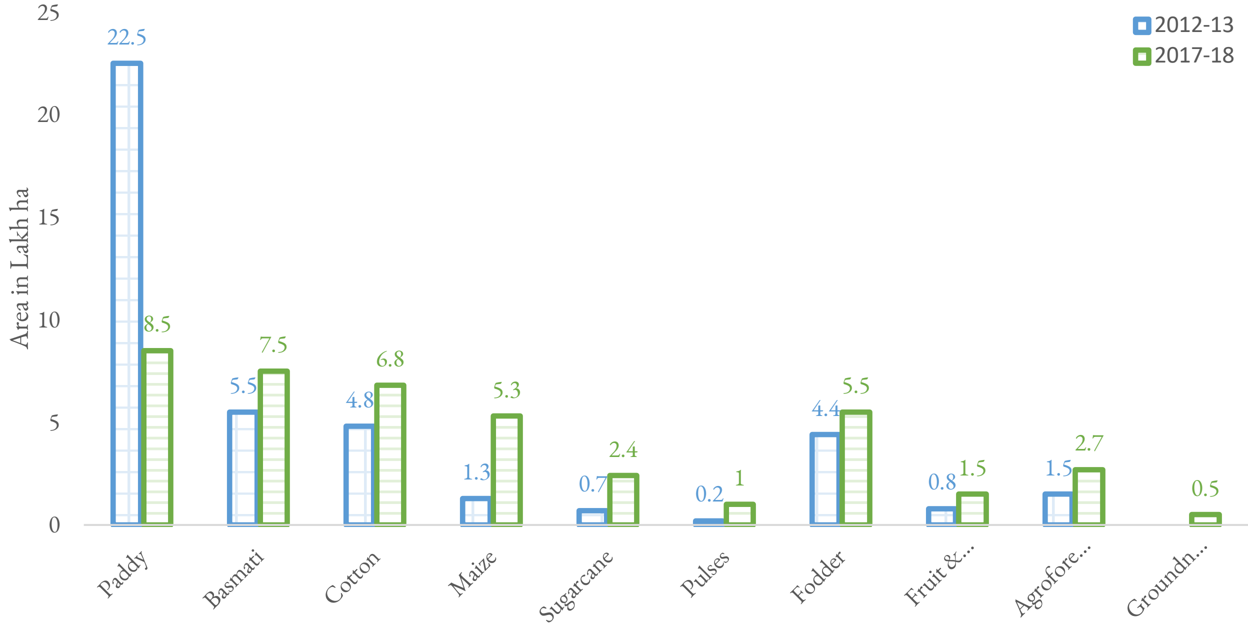


Source: Department of Agriculture, Punjab, 2013

The state government began to be concerned about diminishing returns to the Green Revolution a decade earlier than the 1994-95 break. A crop diversification policy was first formulated in the mid-1980s.

Subsequently, several fresh attempts were made at diversification, including setting various targets for alternative crops, as well as target reductions for paddy (Kaur, et al., 2015). The latter became an increasing focus of diversification because of rice's water intensity: after becoming an important second crop in the Green Revolution cropping system, paddy became a source of concern because of the increased reliance on groundwater for irrigation and rapid decline in the water table. Figure 4 illustrates the most recent plan for crop diversification in Punjab, showing actual cultivated areas in 2012-13 along with target areas in 2017-18, for a range of crops.

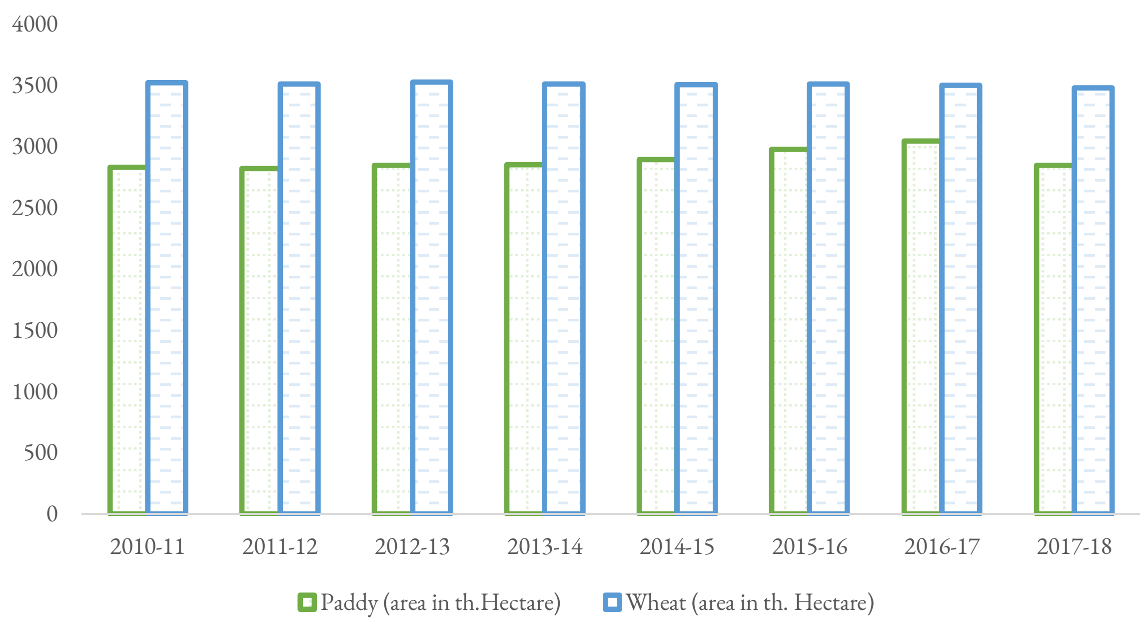
Figure 4: Proposed Plan for Diversification of Agriculture in Punjab



Source: Department of Agriculture, Punjab, 2013-14

However, there has been virtually no progress in achieving these crop diversification targets – compare Figure 4 to Figure 3. Farmers can perform their own cost and benefit analysis before switching to alternatives, and they have not been persuaded to switch, given the relative certainty of their current choices. The latest diversification program was started in some blocks (administrative units smaller than districts) where groundwater was critically overexploited, but it is faltering even in this limited implementation, suggesting that the design of the program is inadequate (Gulati et al., 2017).

Figure 5: Area under Paddy and Wheat in Punjab



Source: Department of Agriculture, Punjab

Aside from specific issues of design and implementation of the latest crop diversification effort, there are broader economic issues that continue as major obstacles to agricultural diversification (Singh, 2019). Farmers are relatively insulated against risks if they participate in the wheat-rice public procurement system. This infrastructure is relatively robust and familiar. Alternatives do not provide this market access and insulation from price and income risk. Even when minimum support prices for other crops (e.g., maize) exist, there is little public procurement, since they are not part of the national system for basic foodgrains. Other factors include the complex variety of alternatives, lack of experience, lack of adequate research and extension, longer growth cycles, greater vulnerability to weather and pests, and lack of market knowledge and infrastructure (Govil 2013). Some of these factors may be manifested as one-time switching costs, while others are ongoing issues.

To summarize, even though the intensive monoculture of paddy and wheat has triggered severe environmental problems, there have been significant and ongoing challenges to achieving any substantial degree of crop diversification in Punjab, despite decades of policies intended to promote it. Indeed, the discussion has continued to the present, when the Covid-19 pandemic created new economic pressures, and the central government announced major reforms in agricultural marketing. We return to these issues later in the paper.

III. Major Environmental Issues

The focus on a narrow range of crops in Punjab has reduced agricultural biodiversity, while expanding agricultural development into new areas has hurt wild biodiversity. The dominant pattern of agriculture has had dramatic effects on the amount of carbon cycling in the atmosphere. Wheat, rice, and soybeans account for a significant amount of the worldwide increase in carbon in the atmosphere over the last 50 years. Burning agricultural residue causes severe air pollution in certain months. Agriculture has contributed to soil pollution through the heavy use of chemical fertilizers and pesticides; this impact on soils has reduced agricultural productivity, aside from the negative health impacts.

Most significantly, agriculture dominated by the monoculture of paddy and wheat has led to overexploitation of water resources in Punjab: groundwater resources in 80% of the state's geographical area are overexploited. All these environmental issues have significant costs that are typically not fully recognized. In this section, we discuss these issues sequentially, as a prelude to an integrated discussion of possible policy responses.

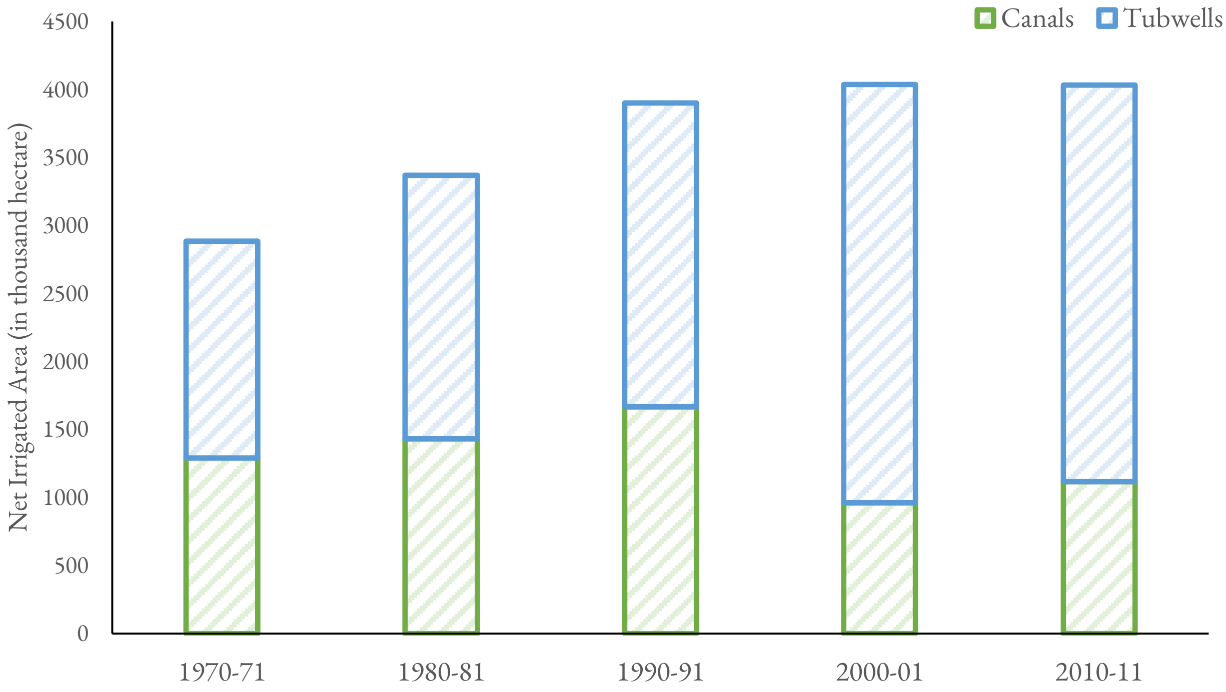
Water

Punjab is not endowed with ideal soils for growing rice; however, the availability of sufficient irrigation water made the rice-wheat pattern in this region highly productive. Rice grown by traditional practices requires approximately 1500 mm of water during a season, and about 50 mm more of water is required to grow seedlings to the transplanting stage. In Punjab, an area with mainly light-textured soils, the actual amount of water applied is much higher than recommended norms (Timsina and Connor, 2001).

Due to the increasing demand for water for irrigation, the amounts provided through the public surface water supply systems are well short of current irrigation needs (Hira, 2009). Reduction in canal capacity due to siltation has reduced canal efficiency far below designated capacity, so traditional canal irrigated area has reduced, while the area irrigated by tube wells has increased. All of this has driven farmers to switch over to the development and use of groundwater, sometimes even low-quality groundwater. To support this reliance on groundwater, the state government has provided easy or subsidized credit for tube well installation, as well as subsidies or other support for electrification of tube wells. With fuel subsidies, diesel-operated pumps – to draw up water from such wells - have become a major fossil fuel consumer in the state. Furthermore, increasing temperature because of climate change increases evaporative demand, which has further increased drawing of groundwater.

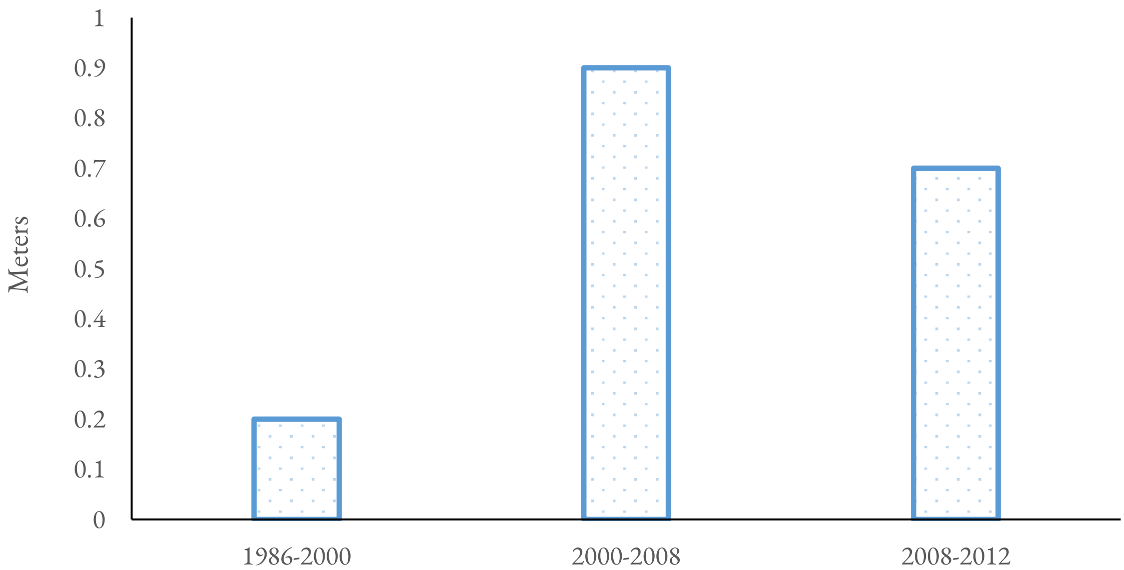
Punjab has the highest proportion of net irrigated area among the states of India. 97.9% of area under agriculture receives irrigation, and 27% of it is from canals, while the vast majority (73%) is from tube wells (ENVIS 2015). Figure 6 displays the proportions of canals and tube wells in irrigation. The unsustainable use of groundwater in excess of recharge is reducing Punjab's water table at an alarming rate. The situation in central Punjab is the worst: the water table in 34 out of 73 blocks has gone down beyond 20-meter depth, and the cumulative fall in groundwater during the last three decades is more than 9 meters (Figure 7). However, in some southwestern parts of Punjab, the water table is rising, because water extraction for irrigation in these areas is limited due to its brackish and saline quality.

Figure 6: Irrigation Methods



Source: Punjab Pollution Control Board, Punjab

Figure 7: Water Table Decline (meters)



Source: Punjab Pollution Control Board, Punjab

These water issues have caused substantial social and economic costs. According to Sekhri (2011), a one-meter reduction in groundwater results in 8% decline in food grain production. As farmers are faced with the need to move to deeper wells, there is a nonlinearity in cost to access groundwater at 8 meters, while almost 100% of these areas had already developed a water table below 9 m by the year 2010 (Kumar, et al., 2010). Small and marginal farmers are proportionately the most affected.

Clearly, agricultural production in Punjab is unsustainable in its current form (Hira, 2009). New management policies and institutions will need to be set up to help Punjab break away from this dilemma. Furthermore, both incentives and controls are called for to regulate farmers' water-using behaviors. The state government has realized the problem and proposed policies and programs for groundwater management. It introduced reforms in agricultural power and an artificial recharge project in Moga district, where all blocks are categorized as overexploited. It enacted the Preservation of Subsoil Water Act in 2009, which mandated delayed paddy nursery and sowing activities by farmers in Punjab. This was to save groundwater by prohibiting sowing and transplanting paddy before specified dates in the hot and dry summer period. Any farmer who contravenes the provisions of the act is liable for a potentially heavy monetary penalty.

However, the groundwater situation worsened in rice-growing areas after the policy change (Sekhri, 2012a). Possibly, farmers responded with an increased number of rounds of irrigation, or more water per irrigation round. In contrast to Sekhri, Tripathi, et al. (2016) found that the groundwater table initially improved after implementation of the 2009 Act, but, thereafter, higher shares of tube wells per total cropped area and increased population density led to a significant decline in groundwater tables (Figure 7). They also note that rainfall and the use of surface water for irrigation protect the groundwater table: seasonality and monsoon rainfall are important, but changing climate patterns are coming into play.

Other approaches for saving water include laser land leveling, alternate wetting and drying, delayed rice transplanting, shorter duration rice varieties, cultivation on raised beds, and crop substitution for rice, mulching rice and wheat with crop residue, irrigation for wheat grown after rice being applied based on atmospheric demand and soil water status rather than growth stage, replacing wheat with other crops, and using furrow-irrigated raised beds. All of these can help, but it is not clear which is best, or if they can make a significant aggregate difference.

Agencies such as the Central Groundwater Authority (CGWA) and Central Groundwater Board (CGWB) are institutionally responsible for enforcing protection of surface and groundwater resources. However, weak or absent coordination between agencies and a lack of regulatory oversight are significant challenges for such enforcement. Lack of clarity over their status, technical capacity shortfalls, under-staffing, marginalization and outdated mandates make these regulatory institutions ineffective in supporting sustainable groundwater management.

Finally, the use of groundwater has been distorted by specific economic policies for years. A critical issue is the effect of water pricing policy on the efficiency and use of water. Resolution of the crisis in Punjab's water resources may need fundamental changes in water pricing and in institutional structures. Pandey (2016) summarizes some potential price-based and quantity-based economic instruments for promoting sustainable use of groundwater, including user fees and tradable groundwater rights, but they have not been tried. Other policies such as subsidies/user charges for promoting investment in or leasing of water-saving methods/equipment and supporting environment for uptake / marketing of alternative crops – to encourage farmers to gradually reduce cropping of water-intensive crops – are also potential instruments to drive sustainable use of groundwater.

Air

Burning of agricultural residue in the fields by farmers at the end of the harvesting season is one of the main sources of air pollution in Punjab, as also a much wider area in northern India. Venkataraman et al. (2006) estimated that farmers all over India burned 116 million metric tons of crop residue in 2001, accounting for a quarter of all black carbon, organic matter, and carbon monoxide emissions, and 9-13% of fine particulate matter (PM 2.5) and carbon dioxide emissions in India that year. Field burning in Punjab, Haryana, and western Uttar Pradesh was the largest likely contributor to these emissions.

Every year, Punjab produces about 20 million tons of rice straw and 17 million tons of wheat straw. Some is used to feed livestock, an insignificant quantity of rice straw is used as fuel in domestic cook stoves, and a small fraction is ploughed into the soil to serve as fertilizer for the next crop[3] – but the vast majority is (81% of rice straw and 48% of wheat straw) burned *in* situ / open fields. This contributes to severe air pollution during March-April and October-November, adversely affecting health (Long et al., 1998; Vander Werf et al., 2006; Kharol and Badarinath, 2006; Pandey et al., 2005), climate and yields (Auffhammer et al., 2006), and the overall economy (Meesubkwang, 2007).

The crop residue disposal method is strongly affected by the harvesting mode. According to Gupta (2012), farmers burned 90% of the residue from rice left by combine-harvesters, while they burned only 1% of the residue that was manually harvested. There are two broad types of rice varieties grown by farmers, coarse and Basmati, and farmers tend to harvest the latter one manually to avoid a loss of grain, as it has a much higher price. But for coarse varieties with support prices and public procurement, combine-harvesters are preferred, being cheaper and faster than hiring labor.[4] Finally, there are ways to utilize residue instead of burning it (Kumar, et al., 2015), but the supply of residue far outweighs potential demand, and residue collection has high costs.

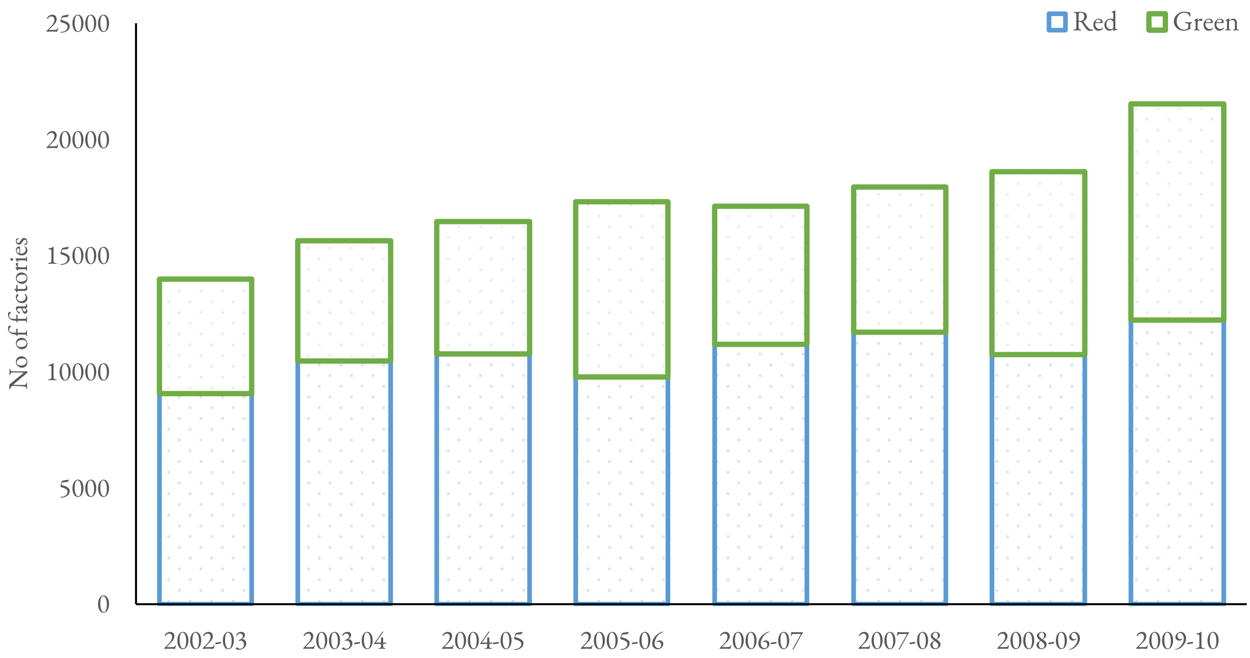
Recently, as the problem of air pollution from burning paddy residue has worsened, it has once again drawn attention to the difficulties that the Punjab agricultural economy faces, as well as the problem of unintended consequences of policymaking. As noted in the previous subsection, the state government tried to reduce the depletion of groundwater in areas growing rice (in rotation with wheat) by mandating delays in sowing paddy. This delayed the harvesting of rice and shortened the gap until the sowing of the next wheat crop. The end result was greater residue burning, to manage the much shorter time window between harvesting one crop and sowing the next.[5]

Recently, the Happy Seeder or similar technologies have been proposed: they allow farmers to plant wheat into the loose residue.[6] Happy Seeder is a tractor-mounted machine that cuts and lifts the rice straw, sows wheat into the bare soil, and deposits the straw over the sown area as mulch, eliminating the need for residue burning. But farmers need to purchase the machine or rely on an underdeveloped leasing market. They must also first uniformly spread the loose rice straw left by the combine-harvester on the field. The evidence is that net gains are small, and not enough to motivate farmers to switch (ANI, 2020). Policy makers have also tried subsidies for, and education about, the technology, but with limited impacts. In 2019, higher-than-ever pollution in Delhi led to India's Supreme Court requiring penalties for stubble burning, but these have been difficult to enforce, and have only exacerbated tensions among farmers.

Given our focus, this subsection has concentrated on air pollution associated with burning of crop residue. Other sources of air pollution include vehicle emissions, cooking and heating fires, and industry. For the most polluted cities of northern India, these three sources may rank above crop residue burning as contributors to pollution and are more persistent throughout the year. Nevertheless, crop residue burning adds to an already serious problem throughout northern India.

In addition, the problem of industrial pollution in Punjab is not a trivial one, and while the Punjab Pollution Control Board attempts to regulate emissions by factories in the state, significant progress is lacking. Figure 8, showing the numbers of factories that are "clean" (green on chart) or not (red), indicates that the number in the latter category has not decreased over time. If Punjab deals with the environmental and economic problems associated with agriculture by accelerating industrialization, this source of air pollution can easily worsen, if not attended to by policymakers.

Figure 8: Number of Factories causing Pollution

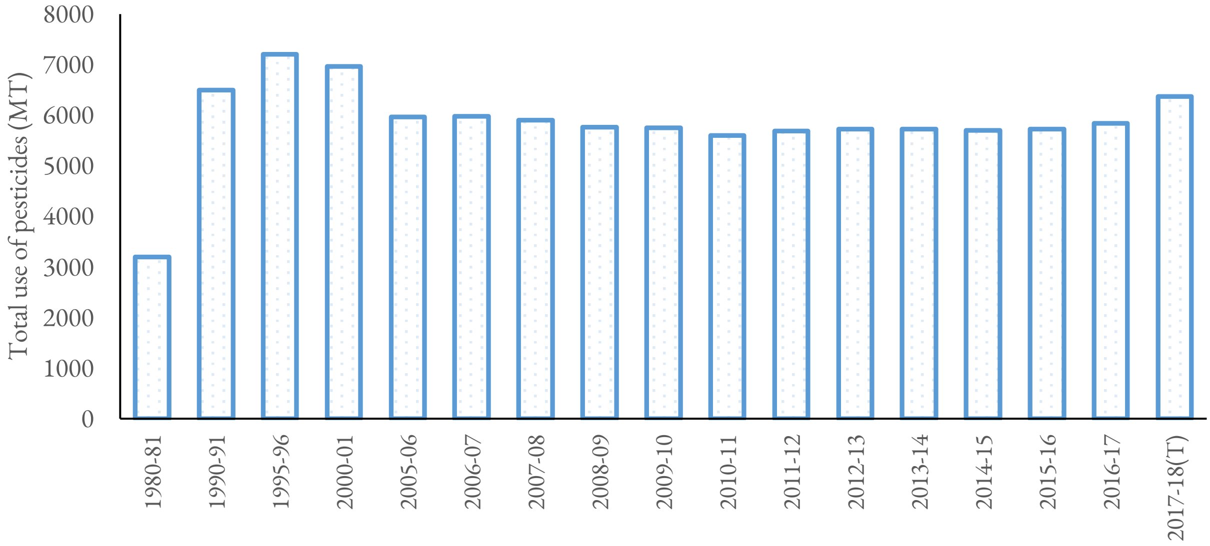


Source: Punjab Pollution Control Board, Punjab

Soil

The soils of Punjab are classified into numerous types, each with different suitability for different crops (Department of Soil and Water Conservation). Crop and cultivation choices, as well as climate patterns, can affect soils, including causing problems such as salinity or erosion. With the success of the Green Revolution, land under agriculture increased from about 75% in 1960-61 to about 80% in 1971, after which it has remained more or less constant. The high wheat-paddy cropping intensity leaves soil with no time for natural rejuvenation. Modern agriculture has contributed to soil pollution, through the non-judicious use of chemical fertilizers, herbicides, insecticides and fumigants. Most of these are stable chemicals: they remain in the soil for long periods without degradation and have cumulative effects. In Punjab, the use of chemical pesticides jumped in the 1980's and has remained high ever since (Figure 9). Pesticide residues are found in soil, air, water and living organisms.[7] Tilling and irrigation deepen the impacts. Ultimately, the continuous use of the chemicals adversely affects soil productivity (ENVIS, 2015).

Figure 9: Total Use of Pesticides (in Metric Tonnes)



Source: Punjab Pollution Control Board, Punjab

The soils in Punjab are generally alkaline in nature with low to medium Nitrogen (N), medium Phosphorus (P), and medium to high Potash (K). Agricultural practices in the past three decades have removed varying amounts of mineral nutrients from the soil, and resulted in a steady decline in its fertility, with respect to these three macronutrients (Tandon and Sekhon, 1988) as well as micronutrients (zinc, iron, manganese). The quantities removed are greater than the amount reintroduced into the soil through fertilizers, which leads to deterioration in soil quality. Sulphur deficiencies (Sharma and Nayyar, 2004) and zinc deficiencies have also emerged.

Field burning of wheat and paddy residues is also contributing to loss of soil fertility. Specifically, 80% to 85% of potassium absorbed by rice and wheat crops remains in the straw, and potassium removal by crop residue is approximately five times as much as is supplied by fertilizers (Chander, 2011). Also, removal of potassium by crops far exceeds that of nitrogen and phosphorus, creating a nutrient imbalance that is very difficult to remedy.

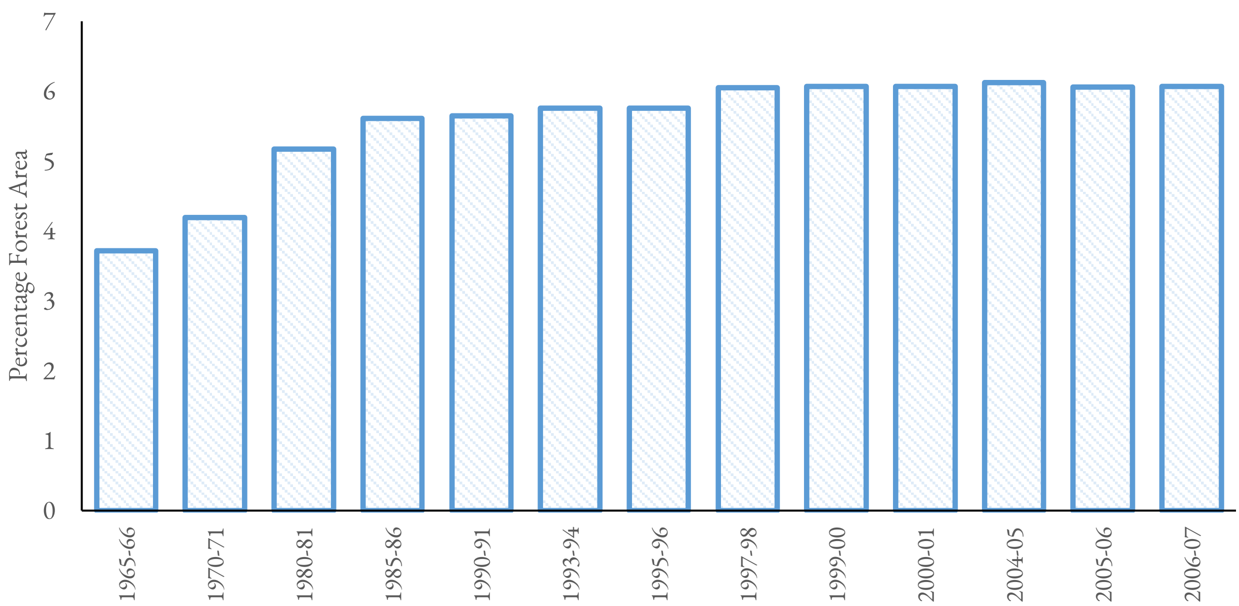
Despite this imbalance, fertilizer use is highly skewed towards nitrogen, with a very low rate of potassium application. This is largely due to the structure of fertilizer subsidies, which are determined by the central government, and beyond the state government's control. Overall, the partial factor productivity of N, P, and K for food grain production has dropped dramatically (Benbi and Brar, 2009). Years of application of inorganic fertilizers have changed the physical and biochemical composition of soil organic matter and caused a decline in the nutrient-supplying capacity of soil. Degraded soils are inherently poor in fertility and crop production, and therefore respond to fertilizer application in the short run, but with negative longer-run consequences. Lower efficiencies and degradation of soil results in uneconomic returns to the users and will eventually lead to even greater overall environmental degradation.

To tackle these issues, the state government has tried various measures for soil conservation: alternative land use, agro-forestry systems (intercropping of trees with field crops) and recycling of crop residue. Specifically, forest species or fruit species have been introduced to places where traditional field crops are increasingly being grown. Intercropping trees with field crops is meant to restore the productivity of soils and increase farmers' profits. Similarly, eco-friendly systems based on the use of nitrogen-fixing trees or trees that are capable of reducing soil pH have some potential to bring about favourable changes in soil properties by promoting soil conservation. However, little research has been done on refining these approaches and on their more detailed impacts, especially on the fine tuning needed to take account of the socioeconomic situations of small farmers. Of course, tree planting can have other potential positive or negative impacts with respect to water and carbon emissions.

Biodiversity

While it is difficult to compare systematically the decline in Punjab's biodiversity with other regions, one can at least document the pattern of change in Punjab to the extent possible. Paleontological records of Punjab indicate that it was floristically and faunistically rich in the geological past. But a review of various components of Punjab's physical environment indicates that intensive and extensive agriculture, over-exploitation of soil and water resources, and consolidation of land holdings have adversely affected natural habitats and biodiversity. Detailed data on diversity of flora is not easily available, but it appears that total forest cover increased slightly or remained relatively constant, at least until 2007 (Figure 10), and likely declined thereafter, with a 2015 estimate of below 4%.

Figure 10: Forest Area as percentage of Total Area



Source: ENVIS Centre, Punjab

More narrowly, in the context of cultivated crops, prior to the Green Revolution, numerous varieties of wheat, rice, maize, millet, sugarcane, pulses, oil seeds, and cotton were documented, being propagated through pure line selection. Subsequently, however, agricultural biodiversity has sharply reduced, with a major focus on the wheat-paddy crop rotation and higher dependence on a narrow range of high-yielding varieties of crops. Even though many new varieties of each crop have been released since the Green Revolution, very few are actually in use by farmers. They have replaced a broad range of traditional varieties which were naturally suited to the climate and soil-related conditions with a small number of high-yielding varieties.

Specifically, the area under input-intensive high-yielding varieties of wheat increased from 69% in 1970-71 to 100% in 2000–01, and has not declined thereafter, and the area under input intensive high-yielding varieties of rice increased from 33% in 1970-71 to 100% by 2005. This has resulted in the severe loss of domesticated floral biodiversity, as well as a decline in areas under other major crops, including maize, millet, pulses, gram, barley, mustard, and sunflower.

In addition to loss of biodiversity in crops, Shiva (1991) highlights the case of animal husbandry, with the introduction of exotic breeds. Together, there are threats to both agricultural biodiversity and species biodiversity in Punjab. As noted, reduced crop diversity has exacerbated soil degradation, depletion of groundwater, and resurgence of resistance in pests, while adversely affecting the population of natural enemies of pests. Additionally, land degradation and soil nutrient depletion have led to clearing of formerly forested areas.

The state government has been aware of its biodiversity loss and proposed a strategy and action plan for conservation of biodiversity in Punjab. Preparation of a Biodiversity Strategy and Action Plan began in 2000: it established a general framework for the state's policy on conservation and sustainable use of biological resources, defined their current status, identified processes leading to deterioration of biological resources, and set out guidelines and specific programs for future actions. The initiatives taken up by relevant departments include promotion of social instruments to protect biodiversity, enactment of specific laws, and promotion of scientific studies. However, unsustainable development models, lack of administrative coordination among institutions and individuals participating in planning, and separate implementation of various developmental projects continue to contribute to the biodiversity loss. Certainly, economic instruments that shape incentives – such as crop insurance or a broader procurement system – need to be strengthened for the purpose.

Climate Change

Due to an increase in concentration of greenhouse gases, the world witnessed warming of 0.74^0C between 1906 and 2005 (IPCC, 2007b). This source predicted a temperature rise in the range of 0.5 to 1.2^0C by 2020 for South Asia, and current data is consistent with this. Higher temperatures negatively affect the growth and productivity of many crops, reducing crop duration, increasing crop respiration rates, reducing crop yield, and numerous other negative impacts (Chauhan, et al., 2011). According to Wassmann, et al. (2009), a 2^0C increase in the mean air temperature will lead to a 0.75% decrease in rice productivity. Ortiz, et al. (2008) predict a similar reduction in wheat yields. Surveys indicated that terminal heat stress in Punjab in 2009-2010 led to an average decline of 5.8% in crop yield compared with the previous year.

A rise in CO_2 should have a positive effect on C_3 plant species[8] in arid regions; however, a rise in temperature would offset this benefit (Timsina and Humphreys, 2006a). On another front, paddy cultivation and residue burning are two significant sources of methane (CH_4). Activities that increase the production of rice, such as the application of organic manures, crop residue, and inorganic fertilizers, also contribute to the increase of CH_4 emissions. Interestingly, irrigated rice is the largest source of CH_4, but also the most obvious option for mitigating emissions, because in Punjab, rice is grown in rotation with wheat on coarse-textured soils of high percolation rates, with a high requirement of irrigation, and constant inflow of oxygen into soils restricts CH_4 emissions (Jain et al., 2000). Improving the irrigation schedule might substantially reduce CH_4 emissions (Wassmann et al., 2000). In fact, continuous flooding emitted more CH_4 than alternated flooding and drying (Mishra et al., 1997). Clearly, there is potential for significant improvements in these emissions, by educating and training farmers.

At the national level, the Indian government was concerned about the impacts of climate change as early as 1992 (Kumar, 2018). In 2008, it released a set of policy programs (eight “missions”) on climate change, together enshrined in its National Action Plan on Climate Change (NAPCC). Furthermore, it had undertaken a voluntary domestic commitment for reducing its emission intensity of GDP by 20-25% by 2020 compared to 2005, to be achieve through the missions focused on mitigation. However, these targets have been pushed out into the future, and remain challenging even so.

Through the Ministry of Environment, Forest, and Climate Change (MoEF&CC), the national government directs each state to identify their climate change concerns and propose mitigation strategies. Depending on each state's specific circumstances, relevant strategies have been formulated as a part of each State Action Plan on Climate Change (SAPCC). As the technologies for mitigation evolve, the strategies identified in these documents are expected to evolve periodically. Punjab's action plan was finalized several years ago (Jerath et al., 2014), although it is now being updated, as is the case for all states. The document covers issues of water, air quality, and biodiversity, as well as emissions, and includes an integrated discussion of sustainable agriculture, as well as identification of various government departments and agencies to be involved. However, in an overall analysis of SAPCCs, Kumar (2018) identifies several problems with formulation and with implementation strategy. Many of the issues raised there are general problems with policymaking in India, including environmental policy, and we discuss them in more detail in the next section.

Discussion

Of all of Punjab’s environmental issues, as detailed in the previous section, the most salient is the unsustainable depletion of groundwater for irrigation. This depletion is supported by policies that favour growing rice to sell to the national foodgrains procurement system, which focuses almost exclusively on wheat and rice. Rice is water-intensive, and surface water resources such as canals are inadequate for the current cropping pattern. The state government’s efforts to perpetuate this system have led to policies that subsidize, or just give away, water and electric power. Other environmental issues of waterlogging, water pollution, soil nutrient depletion, and soil pollution are all symptoms of the same problem, reflecting the production techniques chosen during the period of agricultural development based on high-yielding varieties.[9]

The classic phenomenon of diminishing returns, evident in falling agricultural growth rates in Punjab, is behind behaviours such as overuse of fertilizers, as well as the problems with water use. Diminishing returns to agriculture, and inadequate growth in other sectors, have been reflected in income distress among small farmers. Social problems such as alcohol and drug abuse are also arguably associated with the failing nature of the state’s agricultural economy. It is remarkable, therefore, that there has been no effective policy intervention to tackle the problem of diminishing returns in agriculture. One could more easily understand the relative neglect of associated environmental problems if the agricultural economy were thriving, since externalities, especially those with negative consequences beyond the next election, are easier for policymakers to ignore.

Here, the role of India's national food grains procurement system deserves attention. Without an overhaul of this system, detailed recommendations for reviving agricultural growth in Punjab, however, careful and comprehensive (e.g., Gulati, et al., 2017), may not gain much traction, just as they have not in the past. The lock-in created by the system extends to the state government, which receives significant revenues from charges levied in the markets where wheat and rice are procured.

Changing the national procurement system would force the Punjab government to make significant and difficult adjustments, although there may be potential savings in electric power subsidies if farmers are using less groundwater extracted from deep wells. The current electric power subsidy is extremely fiscally costly, besides incentivizing groundwater depletion. Agricultural reforms announced by the national government in Fall 2020 may not address the heart of the problem, at least in Punjab. The reforms attempt to increase competition and efficiency in agricultural marketing, but without addressing the design and operation of the PDS, leading to anxiety among farmers in Punjab (and elsewhere), and continued protests.

By contrast, Devineni et al. (2020), illustrate a more fruitful approach to policy reform. They consider the issue of groundwater depletion in an integrated national analysis, while linking it explicitly to the goal of national food security. Their calculations demonstrate that it is possible to reconfigure the PDS while preserving national food security and reducing groundwater depletion. Indeed, a redesigned PDS could also increase national revenues from agriculture and reduce energy usage. Even if there are potential issues of switching costs, income redistribution and implementation, it is noteworthy that improvements from reforming the current system might be available with careful policy design.[10]

At the state level, Punjab has proposed policies and regulations to protect the environment, as was illustrated at various points in the previous section, where environmental issues were discussed individually. But the motivation for these policies has been largely in the context of prolonging the already compromised viability of the current agricultural economy. In particular, the recent focus on crop diversification has been to reduce the unsustainable depletion of groundwater associated with rice growing for the PDS, rather than any calculation of the larger implications of this depletion a decade from now. There is no articulation of the harm being done to drinking water resources in the state through this depletion, or overall assessment of the environmental impact of the current shape of the agricultural economy. One example of this absence of an integrated perspective was the state government’s effort to reduce groundwater use by restricting dates of paddy sowing. This led to an increase in rice stubble burning. Much of the cost of increased air pollution was then borne outside the state.

One can argue that highlighting the environmental damage resulting from the current agricultural economy and tying it explicitly to the slowdown in the growth of Punjab agriculture, could lay the groundwork for greater political acceptance of reform. Environmental policy has to be seen as an essential component of, not subsidiary to, policies for reforming agriculture to restore its growth rate. Also, environmental policy has to be formulated and articulated in a way that incorporates other sectors of the economy. For example, drinking water and water for industrial uses are also being affected by groundwater depletion and water pollution, so an optimal policy for water usage must take account of these alternative uses.

In this context, the analysis by Kumar (2018) is instructive: he considers eight different SAPCCs, including Punjab’s. These SAPCCs consider a range of environmental issues, including water, urban habitats, agriculture, and biodiversity, as well as global warming. There are some common issues of lack of stakeholder inputs, lack of local specificity, and lack of clear understanding of the financing of adaptation measures. However, the most striking observation is that over half of Punjab’s notional

SAPCC budget is allocated for sustainable urban habitats. Water and agriculture are assigned much smaller planned allocations, equivalent to only 3-4% of the state budget. Correspondingly, the adaptation actions proposed are deemed to be clearly insufficient, especially without a comprehensive assessment of climate impacts and vulnerability for the agricultural sector.

Putting aside the need for an integrated and sufficiently comprehensive approach to environmental issues associated with Punjab agriculture, even within the context of the existing system and a piecemeal approach to its reform, there are promising policy initiatives that correct or mitigate distortions created by mispricing, such as providing free electricity to farmers.

One approach that is being piloted is to provide payments to farmers that are not tied to electricity use, essentially an income subsidy that makes power affordable, without distorting its price in a manner that incentivizes overuse of water and is environmentally damaging. Such mechanisms do not rely on changes in cropping patterns or public procurement systems, but at least correct the worst input distortions within the existing system. The state government has recently piloted projects in partnership with J-PAL, to test various incentive schemes for reducing water use by replacing free electricity with cash transfers and cutting stubble burning by offering financial incentives (Chandran, 2020). These projects can provide concrete demonstration of impacts and increase acceptance of policy changes by farmers and government officials.

Meanwhile, the neighbouring state of Haryana is more aggressively pursuing policies that reward farmers for switching from paddy to a number of other possible crops, all less water-intensive. These efforts are relatively new, but preliminary estimates suggest that the fiscal costs are not high, supporting the argument that lack of salience of environmental damage, relative to the overall agricultural economy, holds back effective policies.[11]

At the same time, one can reiterate that grand goal setting by the state government in the absence of specific policies to overcome or deal with the technical, financial, and institutional constraints is a futile exercise. Therefore, these constraints need to be relaxed, rather than just announcing unattainable goals. Pilot projects may provide valuable information on the detailed design and implementation of new policies, not just the costs and benefits.[12]

The tendency to set goals without considering constraints and incentives is a weakness of policymaking, in India as a whole, not just in Punjab.[13] At the next policy stage after goal setting, that of trying to achieve those goals, weak institutions and a lack of trained staff have hampered implementation of an appropriate environmental strategy because of inadequate enforcement and monitoring capabilities. One solution could be for the relevant government institutions to work more closely with farmers, as also with NGOs. The latter can often help to bridge the information gap between farmers and policy makers more efficiently and aid the government in designing and implementing programs for sustainable development of agriculture. A related issue for implementation is that the roles of some state government agencies are not clearly defined, making it difficult to assign tasks and accountability. Of course, it is also possible that the weaknesses in policy design and implementation are a symptom of a lack of political commitment to sustainable environmental improvement, which is a much more intractable problem.

Concluding Remarks

This paper identifies several key environmental issues relevant to the state of Punjab, particularly with respect to its current system of agricultural production. It highlights the increasing pressure on natural resources, including water, land, and air. Following previous analyses, we have argued that many of the environmental issues in Punjab are associated with economic policies that have negative spillovers for the state's environment, particularly in the agricultural sector. Although policymakers have tried to identify the major environmental problems and their causes, progress in effecting positive changes has been slow, because of the incentive structures created by existing policies.

As long as the government continues supporting an assured purchase of wheat and rice at guaranteed prices, farmers will likely choose to remain dependent on the wheat-paddy cropping pattern to maintain their livelihoods without taking on new risks. One contribution of our analysis is to suggest that Punjab's environmental problems associated with its pattern of agriculture will not be adequately addressed until the policies that shape that pattern are altered. Those policies, put into place decades ago to provide food security, are now nationally suboptimal, besides leading to environmental degradation in Punjab. The urgency of the state's environmental situation, and the failure of the national government to act, make it a somewhat different case than those discussed in the recent, compelling formulation of how to conduct economic policymaking in India (Kelkar and Shah, 2019). Our suggestion that the failure of national policymaking has dominated state government efforts (whatever their weaknesses) also provides a counterpoint to the label of a "flailing" state (Pritchett, 2009), which puts the blame for governance failures in India in the states rather than at the center. The reasons for this governance failure are complex, and beyond the current scope, but our analysis can be seen as making more general contributions to conceptualizations of governance capabilities.

Even while shifting the policy reform emphasis from the state to the national government, one can still argue that not enough attention has been paid to the protection of the environment at the state level. For instance, even within the current pattern of agricultural production, a very strong case exists for eliminating subsidies (particularly electricity subsidies causing groundwater depletion) that degrade natural resources or harm human health. This change could be supported by the government revising its agricultural economic indicators and associated policy analyses to reflect the depletion and degradation of natural resources, making the environmental costs more visible.

Finally, it is important to recognize that the major environmental issues facing Punjab are not just region-specific problems but national and global challenges. Kumar (2018) also notes the lack of coordination and consultation between the national government and the various state governments with respect to the different levels of climate change action plans. Even the PDS fails to maximize national interests by balancing procurement across different parts of India (Devineni, et al., 2020). Economic policies that encourage conservation and sustainable development, policies targeted at specific environmental problems, and regulatory structures with sufficient enforcement are needed at multiple levels of government. The state and national governments need to work in a coordinated manner to make sure that economic incentives created by their policies do not conflict with the goal of sustainable use of natural resources. Punjab is perhaps one of the most critical regions of India because of its rapid decline in groundwater, and associated problems of water and soil pollution. But air pollution is another example of a rapidly worsening environmental problem that requires coordinated action at different geographic scales, as well as a combination of structural change and changes in marginal incentives.

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NOTES

[1] It is worth noting that this cropping pattern – growing rice and wheat in rotation throughout the year (Gupta, 2012) – is dominant not only in Punjab but in much of South Asia (Hobbs and Morris, 1996), so its environmental problems are also more widespread.

[2]See also Gulati, et al. (2017).

[3] Soil incorporation of rice straw may be conducive to crop disease (Hrynchuk, 1998) or affect rough rice yield due to short-term nitrogen immobilization (Buresh and Sayre, 2007).

[4] The open-field burning of crop residue generated from mechanized harvesting is not restricted to India, e.g., Yang et al. (2008) for China.

[5] A rigorous quantitative analysis is in Singh, et al. (2019).

[6] The combine-harvester leaves two types of residue into the field: loose residue and intact residue. Loose residue is hard to retrieve (Gupta 2012).

[7] Again, it is important to note that these problems are not unique to Punjab: other regions of the globe also suffer from pesticide-caused illness: for example, the Philippines (Faeth, 1994).

[8] This term refers to the nature of photosynthesis. About 85% of plant species, including rice and wheat, are C_3 species.

[9] Water pollution by industry is also a serious problem: even though Punjab is not highly industrialized, it appears to rank poorly in this dimension, with very poor enforcement of anti-pollution regulations (P. Yadav, 2013).

[10] Vijay Kelkar has emphasized to us that such reforms will have many components, and that the debate over how to modify the existing system is not new. He noted the roles of the Food Corporation of India, which procures and stores grains, and the Commission on Agricultural Costs and Prices, which sets MSPs. Another possible policy lever for food security he suggested is the use of international trade agreements or long-term contracts with land-abundant countries. See also Alagh (2003, 2005) for related perspectives. A key point is that these are central government policies; the state government has little or no say.

[11] Based on figures from the Haryana incentive scheme to encourage switching from paddy to cotton (Ravi, 2020), the total cost of one-time payments would be less than 2% of state government revenue from agricultural market fees, or the cost of electric power subsidies. In another example, Punjab and Haryana cut market fees for basmati rice, but Haryana reduced its fees more aggressively (Jayan, 2020).

[12] For example, research into sustainable farming practices could be given much higher priority and funding than it has received so far. Gulati (2012) calculates that the return in terms of increased agricultural GDP is higher for R&D than for any of the existing subsidies.

[13] Kelkar and Shah (2019) emphasize the weakness of governance and regulatory institutions in India, and argue for strengthening such institutions before ambitious policies are formulated and attempted. The case of Punjab has additional nuances. The policies that enabled the Green Revolution and ultimately led to Punjab's environmental problems were ambitious and successful, providing food security for India. The problem now is policy inertia. One cannot wait for institutional strengthening to correct urgent problems.