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HISTORICAL EVOLUTION OF AGRIFOOD SYSTEMS IN HARYANA, INDIA: POLICY AND INSTITUTIONAL EVOLUTION

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ABOUT THIS NOTE

This study examines the evolution of public policy and institutions shaping the agrifood systems in Haryana, India, from 1850 to the present. Public policy is conceptualized as representing state intent (Narain 2018; Dye 2002); in the context of this study, this includes a historical review of public policy spanning the colonial as well as postcolonial eras. Institutions are conceptualized as regularized practices, norms, and codes of conduct that structure repeated human interactions (North 1990). Thereby, in this study, institutions refer to both statutory (enforced and legitimized by the state) and non-statutory (legitimatized by sources other than the state) institutions.

KEY STUDY FINDINGS

1. Present-day Haryana, a part of the Punjab Province during British rule, was discriminated against in matters of agricultural development by the British administration, as the people from this area had participated in the First War of Independence in 1857.
2. The *mahalwari* land revenue system used here during the British period was oppressive and rendered the local population impoverished and indebted.
3. The irrigation systems constructed by the British in the region were limited to protecting it from famine and social unrest; therefore, these systems were characterized by low irrigation intensities. The introduction of green revolution technology in the 1960s presented new challenges for protective irrigation systems because the existing low intensity irrigation design was inadequate to meet farming demands, especially for farmers who wanted to pursue productive irrigation.
4. The green revolution led to monocropping in favor of wheat and rice in the state. This practice was supported by the state's procurement policy as well as policies on flat-rate electricity pricing and subsidies for tube wells.

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5. The green revolution remained confined to the Kurukshetra-Karnal belt, where its effects on agrarian relations were also more pronounced. Nonetheless, it soon came to be associated with steeply falling water table levels and diminishing soil productivity.
6. The mechanized nature of agriculture and the procurement policy of the state shielded the state's farmers from the negative impacts of the COVID-19 pandemic on farm incomes.
7. There is evidence that the state's farmers have the potential to self-organize to meet natural resource constraints; this is a key factor shaping their adaptive capacity.

INTRODUCTION

Haryana is a state in northwest India, first recognized as a separate state in 1966. Though it was one of the major cradles of the Indian green revolution, it is currently undergoing a structural transformation and plays a key role in the industry and service sectors of the country. This note describes how policies and institutions shaping the state's agrifood systems have evolved between 1850 and the present.

This study aims to describe the evolution of policies and institutions that have shaped agrifood systems in Haryana. During the colonial period, this mainly included the state's land revenue policy and policies for the expansion of arable land and irrigation. In the postcolonial period, this refers to forms of state intervention such as the continued expansion of arable area and irrigation, the introduction of green revolution technologies, policies for participatory irrigation management, and the state response to the COVID-19 pandemic. Agrarian institutions, such as systems of water rights and land tenure, and norms of cooperation and collective action, however, exist at a very micro level. This study seeks to capture elements of continuity and discontinuity between the colonial and postcolonial periods with regard to policy and institutions. It focuses on public policy (legitimized and enforced by the state) as well as micro-level statutory and non-statutory institutions (such as the system of water rights, allocation, and distribution) that underpin the state's agrifood systems.

DATA AND METHODS

The study draws primarily on a review of the relevant published literature, archival material, and a few key informant interviews. Key informant interviews (KIIs) were conducted mainly to validate and update some of the findings from the literature review. The relevant literature was selected using a snowballing technique. Given that the state's agrarian institutions operate at a micro level, this study draws on several micro-level case studies to show how such institutions have manifested and evolved. The initial search for pertinent literature was used to identify further literature to be reviewed to build a coherent storyline.

STUDY FINDINGS

Agrifood Systems in Haryana During the Colonial Rule

The geography of present-day Haryana was captured by the East India Company on December 30, 1803, from Daulat Rao Sindhia. It then became a part of the Delhi Province under what was then known as the North-Western Province (NWP). The people of Haryana played a significant role in the first war of independence in 1857, resulting in many casualties. After the British suppressed the mutiny, the Nawab of Jhajjar, the Raja of Ballabhgarh, and Rao Tula Ram of Rewari were deprived of their territories. These were handed over to the rulers of Nabha, Jind, and Patiala of the Punjab Province as a reward for their loyalty to the British Empire (Sharma 2016). Thus, Haryana was separated from NWP and tagged to Punjab in February 1858.

Consequently, the region became the sociocultural backyard of Punjab and was discriminated against in matters of development (Amrohi 2013; Sharma 2016; Parshad 2018). The fact that the people of Haryana had participated in the mutiny of 1857 was key in influencing British attitude and policy toward the state – the British took a hostile stand. On the one hand, they followed a repressive land revenue policy, and on the other, they accorded a low priority to the development of agriculture in the region. The state was seen mainly as a source of supply for soldiers for the British army and for draught animals. Haryana remained a part of Punjab (first under the administrative control of Punjab Province from 1858 to 1947 during British colonial rule, and then later as part of the Indian state of Punjab post-independence) until November 1966, when it came to be recognized as a separate state.

Oppressive Land Revenue Policy During the Colonial Rule

The British introduced three distinct land revenue assessment systems in India – the zamindari settlement (permanent settlement) in Bengal; the *ryotwari* settlement in Madras and Bombay, and the *mahalwari* system in North India (Parshad 2018). Haryana witnessed the *mahalwari* system, where the settlement was made directly with the village community, or *mahal* (estate), under the instructions of a settlement officer, who would fix the land rent to be paid by the peasants with the help of a *lambardar* (village headman). The *lambardar* was solely responsible for all recommendations, the survey of lands, the preparation of records relating to land rights, the settlement of land revenue and demands in the *mahals*, and the collection of land revenue.

A detailed account of the land revenue policy in the region is provided by Amrohi (2013), Singh (2012), and Parshad (2018). During colonial rule, land revenue was one of the key revenue sources for the government and was used by the imperialistic power to secure its colonial ambitions. However, the land revenue policy followed by the British in Punjab was different from that of the rest of India. Besides, even within Punjab, the land revenue policy followed was different for south-eastern areas in Punjab (present-day Haryana).

"The experience of the south-eastern region under British Rule was both qualitatively and quantitatively different from that of the Punjab province as a whole. The process of agricultural expansion, which marked the entire region, and had a significant impact on all aspects of life, was somewhat absent in this part of the region. The continued backwardness and underdevelopment of the tract, despite overall economic development, brought about a situation with its own specific problems and variations peculiar to south-eastern areas alone" (Amrohi 2013, 18).

While the land revenue was fixed at 40% for India as a whole, it was approximately 50% in Punjab. Since south-eastern areas in Punjab were further discriminated against, land revenue was collected stringently. The land revenue extracted from Punjab increased periodically. Between 1817–1818 and 1861, it increased 182%, 24% between 1860–1861 and 1900–1901, and 20% between 1900–1901 and 1931–1932 (Amrohi 2013). Among all the districts in Punjab, Karnal contributed the most toward land revenue as a percentage of net income.

Land revenue was a tax that the peasantry had to pay even under extreme circumstances, and it remained a compressing burden for the peasantry throughout the colonial period (Amrohi 2013; Sharma 2016; Parshad 2018). They were expected to pay their dues by the appointed time under stringent conditions, as defaulting on land revenue meant loss of land ownership. No excuses were accepted with regard to nonpayment of revenue. Consequently, land revenue became a major reason for farmer debt.

The land revenue demanded from the south-eastern areas of Punjab rose steadily between 1860 and 1932 (Amrohi 2013). For instance, the total land revenue demand in 1860–1861 was 41 lakh rupees, which increased to 53 lakh rupees in 1900–1901 and further to 73 lakh rupees in 1931–1932, i.e., a 30% increase between 1860–1861 and 1900–1901 and a 37% increase between 1900–1901 and 1931–1932. Overall, the demand for land revenue increased by 85% between 1860–1861 and 1931–1932. In 1860, the highest revenues were collected from Gurgaon (11.5 lakh rupees), followed by Rohtak and Karnal (approximately 9 and 8 lakhs rupees, respectively). Comparatively, Hissar and Delhi paid less (approximately 4 lakhs rupees each), and Ambala and Sirsa paid the least (2 lakhs rupees each).

On account of its political positioning and participation in the first war of independence of 1857, the region's agricultural development was not prioritized by the colonial state (Amrohi 2013; Parshad 2016). It was mostly seen as being only suited for the supply of draught animals to the rest of Punjab and other parts of the country. Animal husbandry emerged as a subsistence-level economic activity, yet it never reached commercial proportions because the emphasis was on draught cattle rather than dairy cattle or the commercialization of dairy products. Over time, the region became impoverished and emerged as a major recruiting ground for the British Indian army, which was the only source of employment and sustenance under conditions of economic stagnation and backwardness.

Expansion of Arable Land and Irrigation under the British

In addition to the repressive land revenue policy, two other colonial policies affected the agrifood system in the south-eastern areas of the Punjab Province. These were the expansion of arable land and the construction of irrigation systems. Between 1850 and 1970, a steady expansion of arable land took place all over North India, including present-day Punjab, Haryana, Delhi, and Chandigarh (Richards et al. 1985). The expansion of cultivable land was accompanied by the loss of woodlands. Though most of this expansion occurred during 1850–1890, amounting to a total increase of 28%, the expansion continued until 1970, adding another 16% of cultivable land. The districts on the desert fringe (especially Mahendragarh between 1890 and 1970) and the plains experienced the greatest growth (with Karnal, Jullundur, Patiala, and Sangrur showing the highest rates of expansion).

While clearing new lands for plowing was the most common investment in agriculture in the colonial period, irrigation works, leading to land reclamation, were another (Richards et al. 1985). Some canals that were dug by the British were beneficial to the areas that constitute present-day Haryana (Kumar and Dangi 2018.). For instance, the Western Yamuna Canal, built by Sultan Feroz Shah in the fourteenth century, was renovated in 1886 since most parts of the canal had fallen into disuse. In 1868, another big canal irrigation project (Sirhind Canal) was launched by the British. This canal was planned to take water from the Sutlej and irrigate the districts of Hissar, Haryana, Ludhiana, and Ferozepur of the Punjab Province. Similarly, the Sirsa Branch Canal was dug during 1885–1895.

The construction of these canals had an important effect on altering the local cropping patterns. For instance, the canals built by the British in the villages around Kakroi in Sonipat had an impact on agricultural production (pers. comm. Pratik Mishra, post-doctoral Research Associate, Lancaster Environment Center, Lancaster, England, United Kingdom, September 27, 2023). Because the water in the region was brackish, only chana (chickpea) and other millets or lentils were cultivated early on. However, with the building of the canal networks during the British time, there was enough water to even grow sugarcane.

The Concept of Protective Irrigation: Genesis and Historical Evolution from the Colonial to the Postcolonial Period

Apart from the expansion of arable land, the other element of continuity between the colonial and postcolonial periods was the construction and expansion of irrigation systems. Just as elsewhere in India, these constructions in areas of present-day Haryana were guided by the concept of protective irrigation (Jurriens and Wester 1995a, 1995b; Mollinga 2003), which was part of the phase of planned economic development. This highlighted the continuity in state policy. Yet, the actual practice of protective irrigation evolved historically both during the colonial and postcolonial periods. This, on the other hand, represented the discontinuity in state policy.

Another element of discontinuity was in terms of the relationship and compatibility between farming practices and the design assumptions of the protective irrigation systems. Till the British period, the state’s protective irrigation systems functioned as intended. However, after the colonial period and the introduction of green revolution technology, there was a mismatch between the goals of protective irrigation and those of farmers, who now wanted to engage in productive irrigation. This created ideal conditions for institutional evolution on how water rights were realized in practice, pointing to a distinction between the concretization of water rights and their materialization.

As opposed to productive irrigation systems, which match water availability from irrigation systems with the crop water requirements (and also the dominant practice worldwide), protective irrigation systems are designed to meet only part of the total crop water requirements. They have specific technical, organizational, and institutional characteristics. Appreciating the concept of protective irrigation, the foundation for which was laid during the colonial period, is essential in understanding the present agrarian context of Haryana and in assessing the performance of canal irrigation systems. Technological and institutional evolution within protective irrigation systems continues to characterize agrifood systems in the state.

The fundamental idea behind the concept of protective irrigation during the British period was to spread the water thinly over a large area and reach out to a large number of farmers rather than meet the entire crop water requirements of only a few (Jurriens and Wester 1995a, 1995b; Mollinga 2003). This was to prevent famine and political unrest and to encourage the cultivation of cash crops. The principle of protective irrigation has been adopted in India since the middle of the nineteenth century (Jurriens and Wester 1995a) and developed by the British administration at a time when the subcontinent frequently faced famines.

Initially, irrigation was intended to benefit as many people as possible with a small but sufficient amount of water to protect them from total crop failure. This was in accordance with two of the official British development objectives for India: protection from famine and maintenance of political security. However, when protective irrigation systems were first built in India, colonial authorities did not use the term "protective irrigation." Instead, the land with protective irrigation was referred to as "area protected." It was not the same as an irrigated area as an area was considered protected even when only a part of it received water. In the 1860s, in Punjab, it was considered enough if 42.5% of the surface area received water. Thus, when an area was "protected" by irrigation, it meant that water was available for at least 42.5% of the surface area and there was sufficient water to guard it against famine and crop failure. It did not imply that there was enough water to irrigate all the crops of a particular holding.

In the last quarter of the nineteenth century, however, protective irrigation acquired a second meaning when such systems came to be distinguished from productive irrigation systems (Jurriens and Wester 1995a; Mollinga 2003). In the first half of the nineteenth century, irrigation schemes were designed with the goal of maximum return with minimum investment. This approach proved to be quite profitable as capital expenditure could yield a return of up to 69.5% (Whitcombe 1983 and Stone 1980 cited in Bolding et al. 1995). These irrigation systems came to be referred to as productive irrigation systems.

However, after 1860, when the Crown assumed direct control of India from the East India Company (Mollinga 1998), certain changes were introduced that had implications for irrigation development. This period also witnessed changes in the manner in which public works were financed. An independent public works department was established, and the irrigation policy underwent a change following the report of the Indian Famine Commission (1878–1980).

In its report, the Indian Famine Commission drew attention to the benefits of irrigation in preventing famine. It defined the general policy that the British Government should adopt in dealing with famines (Narain 1922) and emphasized the need to anticipate famines and be prepared for them. It recommended that the government take direct measures to prevent famine and provide relief. The proposed solutions included expanding irrigation and railways and promoting the diversification of occupations.

As a result, protective irrigation works came to play an important role during British rule. According to Narain (1922): "*Famines have been frequent under British rule, but thanks to the chain of protective railways, and the great irrigation works, they do not cause so much suffering now as they did in the past. Very great progress has been made in famine protection and famine relief*" (243). He continues:

"It would be difficult to overestimate the value to the country of these fine systems of irrigation works which may be said, with some slight reservations in respect of the Cauvery works in Madras, to have been entirely created by the British Government within the last eighty years. They irrigate annually over 11 million acres and completely protect from famine an area, which, except in the Madras and Orissa deltas, may be said to vary from two to four times the area annually irrigated. In some parts, as in Sind, there can be no cultivation, and therefore no population, without canal irrigation. In others, the effect of the works in maintaining or raising the level of the sub-soil water, on which the well irrigation depends, is of the utmost value and importance. The value of the crops irrigated by the canals in a single year is about equal to the whole capital cost of the works, and in years of famine, the produce of the irrigated area, being largely available for transport to distressed tracts, becomes an important item in the general food supply of the country" (Report of the Indian Irrigation Commission 1901–1903 cited in Narain 1922, 290).

This notion of protective irrigation remained in use till 1964, when the benefit/cost (B/C) ratio was introduced as an investment criterion. Since then, it has not been used to indicate a formal category of irrigation scheme as intended by the Indian Famine Commission.

In the 1990s, protective irrigation came to acquire a third meaning, indicating a form of irrigation that had certain technical, organizational, and socioeconomic characteristics specific to drought-prone areas of the subcontinent (Jurriens and Landstra 1989).

The technical characteristics of protective irrigation systems involved spreading the water thin over a large area and a number of farmers. Farmers were expected to cultivate crops that required less water. Further, water was rationed based on available supplies. A supply-orientated approach implied that these systems were characterized by low irrigation intensities and high duties [**1**] (Jurriens and Landstra 1989). The intensity of irrigation in many systems was often less than 100% (Tilak and Rajvanshi 1991). By restricting irrigation by canals to a part of the irrigable areas, and by further limiting cultivation in those parts to one crop per year, the water was spread over a large area. Fine-tuning supply to demand, which is done to maximize yield, was not the objective. The supply-orientation approach resulted in maintenance costs being kept low (as these systems were unproductive systems and yielded little revenue). Such an approach also required fewer regulating devices for controlling water levels between the source (such as a weir or a dam) and the outlet command areas at the farmers' level (Mollinga 2003).

These technical design characteristics further translated into specific organizational and institutional characteristics, such as low management intensity and hierarchy. Since the aim was not to match supply with demand, control structures were limited and thus had a low management intensity (Jurriens et al. 1996). Besides, the supply-oriented approach of protective irrigation systems fit well with the top-down organizational structure of the irrigation department and was based on the principle of an upward flow of information and a downward flow of instructions.

Another organizational characteristic was the institutional system of water rationing, which appeared to operate as a system of designed scarcity (Jurriens et al. 1996). This system of rationing scarce water supplies took the form of *warabandi* irrigation in northwestern India and Pakistan, *shejpali* in western India, and localization in South India (Mollinga 2003). *Warabandi* is a system of water allocation in which water is allocated to farmers in proportion to the size of the land-holding; *shejpali* is a system of water allocation in which farmers make applications for water and these are sanctioned based on water availability in the reservoir. A detailed discussion of these systems follows in subsequent sections of this study.

According to Jurriens and Wester (1995a, 1995b), the protective irrigation schemes in India under British rule functioned more or less satisfactorily. This was because of several reasons. First, the population was smaller; second, agricultural production was mostly at the subsistence level, given the initial objectives of the irrigation system; and third, overall, production capacities had improved from what had been before the introduction of irrigation. Therefore, low irrigation intensities and agricultural yields were acceptable because they did offer protection from famine.

After independence, however, the situation changed somewhat drastically. From the 1960s onward, the population explosion triggered a shortage of food and fiber. The situation was exacerbated due to several droughts during the monsoon period in the early years of planned economic development. Attaining self-sufficiency in food production became imperative for the newly independent India. With agriculture beginning to be remunerative for the rural population, farmers tried to increase production by irrigating more. Programs to improve seeds, fertilizers, pesticides, and marketing had a considerable impact on production, especially after the introduction of higher-yielding varieties (HYVs) in the 1960s. The net outcome was an increased demand for water, which the protective irrigation systems were not designed to fulfill. This created conditions for an institutional evolution of the supply-constrained irrigation systems of the north, including the *warabandi* system, which is still prevalent in Haryana.

Warabandi Irrigation: Institutional Evolution in the Agrifood Systems of Haryana

Warabandi is a form of protective irrigation prevalent in present-day Haryana and much of northwest India and Pakistan. As a system of water allocation, *warabandi* covers an area of approximately 24 million hectares (mha) in India and Pakistan (Bandaragoda 1998) [**2**].

The genesis of the *warabandi* system stemmed from a process of trial-and-error allocation of water to farmers during British times (van Halsema 2002). It is a supply-based system where water is divided among landowners according to the size of their landholdings (Malhotra et al. 1984; Malhotra 1988; Berkoff 1990; Bandaragoda 1998; Narain 2008a, 2008b). Thus, water rights are defined in terms of a time schedule to receive water. This is an interesting and important dimension of the irrigation and agrarian context of the state and warrants a detailed discussion for three main reasons. First, most discourses on water rights and market creation (see, for instance, Anderson and Snyder 1997) assume volumetric definitions of water rights. Second, in mainstream discourses on irrigation and agrarian reforms in the country, the definition of water rights itself has been a blackbox. Third, a detailed understanding of how water rights are defined and materialized has conceptual significance in that it has the potential to impart a sociotechnical perspective on water rights, drawing attention to how the definition and materialization of rights is shaped by an interface of technology and institutions (Narain 2008a, 2008b). Water rights are embedded in the design of irrigation systems in the state and do not exist in a sociotechnical silo.

At the tertiary level, water is allocated to farms through ungated proportional modules, which draw a fixed allocation of water from the main and secondary systems. Farmers are expected to take this fixed discharge of water on the assigned date and time of the week as specified in the *warabandi* schedule prepared by the state's irrigation department. The distributaries are supposed to operate at full supply level (FSL). This basis of a water right is sanctioned under the Haryana Canal and Drainage Act of 1974.

In principle, the *warabandi* system is not designed to be flexible in terms of duration, rate, and frequency of irrigation (Narain 2003a, 2003b). The distributaries are designed to be operated at FSL, and water is drawn through fixed, ungated structures such as the adjustable proportionate module (APM) or open flume at the tertiary or *chak* (outlet or watercourse) level. Every farmer is assigned a specific time and date of the week when he is entitled to take the full flow of water flowing from the distributary. Calculations are based on 168 hours in a week. If there are, for instance, 168 hours in a *chak*, the allocation time for each acre is one hour, meaning an acre will get an irrigation turn of one hour. The amount of water allocated to a watercourse is calculated according to a predetermined, scheme-wide water allowance and the size of the area commanded by the watercourse.

In practice, however, farmers work within the constraints of the *warabandi* system such that it operates as a quasi–demand-based system. As noted, the designed low irrigation intensities and high duties worked well till the period of colonial rule. However, this connection was broken in the post-independence era, especially with the introduction of the green revolution, which demanded the timely application of specific quantities of water in combination with HYVs of seeds and other agricultural inputs such as pesticides and chemical fertilizers. A conflict emerged between the goals of protective irrigation that was in practice and productive irrigation, which the farmers wanted to follow. Farmers started pursuing various strategies at the individual and group levels to reconcile the goals of protective irrigation with those of productive irrigation. An analysis of these strategies helps us understand the institutional evolution in the mediation of the 'designed scarcity' in the agrifood systems of the state and draws attention to the role of social capital in shaping the adaptive capacity of the state's farmers.

The most detailed account of these strategies is provided by Narain (2003a, 2003b), which is based on an ethnographic study of two villages in the Rohtak and Jind districts of the state. One of the most prevalent practices observed among farmers was the exchange of allocated time turns for irrigation. The *pucka warabandi* (formal *warabandi* schedule made by the irrigation department) schedule for each outlet is prepared by the irrigation department. The legal basis of sanction is Section 55 (A) of the Haryana Canal and Drainage Act of 1974. The schedule specifies the day, time, and duration each week when a farmer is entitled to receive a prespecified quantity of water. Since such a specification may be inadequate for farmers to meet their crop water requirements, it is reconciled by exchanging or accumulating irrigation turns with other farmers to make the water right more effective. For instance, if a farmer's turn to irrigate is from 9 am to 9:15 am on Monday, but he finds that the water allocated to him during that period is insufficient, he may borrow 15 minutes from another farmer and perhaps another 15 minutes from another farmer, with a promise to return the 'turns' in the future. This way, he accumulates 45 minutes over his allotted time to irrigate at a stretch, which makes the water right more effective.

It is important to note that time exchanges are prohibited under the Haryana Canal and Drainage Act of 1974. However, they are followed widely and legitimized based on *bhaichaara,* which translates to 'a form of brotherhood or fraternity.' *Bhaichaara* represents a form of social capital that is mobilized to overcome the constraints posed by the designed scarcity created by the *warabandi* system as a form of protective irrigation. *Bhaichaara* is an organic institution in that it is socially embedded. Respondents describe *bhaichaara* as giving up an individual good for a larger good; the term is used in various contexts, such as a *bhaichaara* panchayat, which refers to a form of local governance parallel to the statutory panchayat. There is an element of reciprocity in these time exchanges, captured by the expression commonly used to describe them: "*bhai ka diya, bhai ka liya*" (taken from brother, returned to brother) (Narain 2003a, 2003b). As a consequence, *bhaichaara*-based time exchanges have become integral in shaping the adaptive capacity of farmers in response to a regime that is scarce by design.

Though water rights are defined by the state, they are realized through normative systems outside the state. This is evident in the distinction between policy and practice of water rights as well as water allocation and distribution. Statutory and non-statutory bases of legitimacy equally shape water access in the *warabandi* system, pointing to the existence of legal pluralism (von Benda Beckmann, 2001) in the state's agrifood systems. Water rights in the *warabandi* irrigation system were defined by state law and have legitimacy under the Haryana Canal and Drainage Act of 1974. However, they are realized based on the *bhaichaara*-based time exchanges. Though these swaps of allocated time are prohibited under state law, they have a strong legitimacy stemming from the strength of social sanction.

Time swaps are more common for crops such as wheat in the *rabi* (winter) season, paddy and sugarcane in the *kharif* (monsoon) season, and water-intensive crops, indicating the relevance of this strategy to filling the demand–supply gap created by the *warabandi* system (Narain 2003a, 2003b). Accumulating timeshares is a particularly common strategy for farmers with very small landholdings, such as one acre or half an acre. For instance, if farmers A, B, and C have one acre of land and 15 minutes each to irrigate, they exchange and accumulate their turns such that each farmer gets 45 minutes to irrigate at a stretch. Time exchanges also cut across seasons. For instance, if, in the *kharif* season, farmer A has sown paddy and farmer B has sown sorghum, farmer A, who has a greater crop water requirement, borrows an irrigating turn from farmer B. In the *rabi* season, if farmer B has sown wheat, and has an extra water requirement, he takes his allowance back from farmer A. It is common for tailenders, who are usually deprived of a fair share of water due to head-tail differences, to skip irrigation in one season (*kharif*) and accumulate water shares so that one crop can be grown in the *rabi* season. In *kharif*, they concentrate on crops such as sorghum, millet, and cotton as they consume less water and also because farmers rely on the rains for *kharif* cultivation.

The practice of time exchanges also cuts across *thola*s (ancestral family units), though it is more common among members of a *thola* who own adjacent pieces of land to swap allotted irrigation time across outlets as well as seasons.

The institutionalization of time exchange, albeit informal, is attributable to 1) the design features of the canal irrigation systems that allocate water scarcely in relation to the crop water requirement; 2) well-defined water rights that have a basis under the Haryana Canal and Drainage Act of 1974; 3) the rigidity in the water allocation schedule and the small size of landholdings, which lead to short duration irrigation turns, making irrigation impractical and inefficient; and 4) the existence of plural legal repertoires (Narain 2003a, 2003b).

The study of time exchanges in the agrifood systems of Haryana points to an institutional evolution within a sociotechnical context of protective irrigation that has its roots in the colonial period but was shaped further with the spread of the green revolution technology in postcolonial India in response to the measures taken to overcome the agricultural stagnation created during the colonial rule.

It is equally interesting to learn how the institution of time exchange works in relation to other institutional arrangements in agriculture, such as tenancy arrangements (Narain 2003a, 2003b). When a landowner gives the land out to be tilled under a tenancy arrangement (*theka*), the arrangement is inclusive of the water rights share of the land. It is a common practice among small landowners in Haryana to take land on *theka* from other farmers. Larger farmers also give out their lands on *theka* in smaller parcels or fragments to more than one small farmer at once or simultaneously cultivate their lands and those of other farmers. Water rights, in these contexts, are maintained under *sajedaari* arrangements, wherein the landowner provides the piece of land and its concomitant share of water. The landowner and the tenant contribute equally to the agricultural inputs and share the produce equally. This arrangement is known as *addha*, literally meaning 'half-half.'

Given how water rights are defined in Haryana, what can their study contribute to the neoliberal discourse on market creation? Narain (2003a, 2003b) notes two different types of sale of water rights – one where the farmer sells off his water right share for an entire year when not intending to irrigate from the canal, and the other, when he sells a specific turn, for instance, for a week, when he does not need to irrigate in that turn. The rate varies depending on the demand; during the summer, this could be INR 200 per hour [**3**], and during the winter season, it is in the range of INR 100–150 per hour (Narain 2003a).

However, time swapping is a more common practice than selling it because lending a timeshare creates the basis for future entitlement. Once a farmer lends his timeshare to another, the latter is under an obligation to return it. Since farmers would typically sell their turn only after meeting their requirements and obligations, Narain (2003a) posits that the possibility of vibrant water markets emerging under *warabandi* irrigation is very thin. This supports the results of other empirical studies on market creation in surface irrigation, such as those of Bauer (1997), who investigated the functioning of water markets in Chile after the creation of the National Water Code of 1987 and found the functioning of the water markets to be sluggish.

Other strategies for increasing control over irrigation, over and above time exchanges, have been digging tube wells, pilfering water along the canal, or applying for rice shoots [**4**] (Narain 2003a, 2003b). Though it is common to supplement canal water irrigation with groundwater, farmers typically wait for the canal, as canal water is much cheaper. However, if a farmer needs to irrigate outside his schedule, he tends to pump groundwater. The farmer may still pump groundwater if he feels that his water entitlement is inadequate relative to his requirement. According to Narain (2003a) there is a tendency among farmers who buy groundwater for irrigation to dig their own tube wells to have even greater control over groundwater availability. Groundwater sale and purchase conditions vary, depending on the relationship between the buyer and the seller. It is often sold at a rate of INR 40 per hour. Alternatively, the buyer may provide the seller with the required amount of diesel. A third arrangement is a contractual annual arrangement where the seller provides groundwater at the rate of INR 1,000 per acre per annum. Tailenders rely more on groundwater irrigation on account of seepage losses. They buy groundwater from sellers closer to the head reaches where the groundwater is less saline owing to its proximity to the canal; seepage from the canal washes down some of the salts.

An analysis of these forms of transactions points to the diversity of farmer responses to a regime of designed scarcity in the state's agrifood systems and also to the variety of institutional arrangements shaping farmers' access to groundwater. Though the literature on *warabandi* irrigation is extensive, there are few detailed ethnographic studies other than Narain (2003a, 2003b) that offer insights into the actual irrigation practices in the state. Studies of *warabandi* irrigation in Pakistan also offer similar analyses and could be referred to for additional insights [**5**].

Policies for Participatory Irrigation Management: Genesis, Global Context, and Implementation

Participatory irrigation management (PIM) is an important dimension of the agrifood systems of Haryana that helps trace the evolution of irrigation policy in the state. In the late 1990s, it emerged in response to the global trend of transferring the management of irrigation systems to farmers. This was carried out under different labels such as irrigation management transfer, irrigation management turnover (IMT), or PIM [**6**].

There were several drivers of PIM policies in the state in the 1990s. These included 1) empirical evidence that communities were capable of managing natural resources sustainably on the strength of institutions or rules in use (Ostrom 1990); 2) the participation paradigm in development, which emphasized that government schemes would be ineffective in delivering public services unless the users were involved themselves (Korten 1980; Wiener 1975; Uphoff 1992); and 3) a strong push from donors and funders who saw community participation as a way of promoting good governance and stakeholder engagement. At the policy level, concepts such as the subsidiarity principle and the territoriality argument (Korten 1980) were instrumental in creating a policy push in favor of policies for PIM. Governments introduced policies and enacted laws and legislations in response to such pressure, often with relatively little internal commitment or internalization of what goals were to be accomplished through policies for community-based conservation.

In Haryana, strategies for the formation of water users' associations (WUAs) were advocated in the late 1990s under the World Bank–supported Haryana Water Resources Consolidation Programme (HRWCP). In 1995, the government of Haryana issued a policy resolution that lining of water courses would only be carried out if farmers on the watercourse had been organized into a water users' association. Two organizations were engaged in the formation of WUAs in the state – the Command Area Development Authority (CADA) and the Haryana State Minor Irrigation and Tubewells Development Corporation (HSMITC) (Narain 2003a). The main role accorded to WUAs under policies for PIM was the lining of the water courses and the maintenance thereof. Interestingly, the irrigation department never came to be identified as a direct actor in the formation of WUAs.

Several criticisms were made regarding the policies for PIM in the state. The first critique was the limited potential for reform through the formation of WUAs (Narain 2003a). This related to the technological context in which the policies for PIM were meant to be implemented. The prevalence of *warabandi* as a sociotechnical system comprising a certain physical infrastructure and corresponding institutions for water resource allocation (and not just as an institutional system of water rationing) in itself limited the potential for reform of the irrigation systems through PIM. *Warabandi,* as explained in earlier sections of this study, is a supply-driven system in which irrigators receive fixed supplies of water that are supposed to be appropriated in the time slots allotted to them as per the *warabandi* schedule. Users have a very limited role in the overall operation of the system. They are mere recipients of predetermined, fixed quantities of water. This is in contrast, for instance, to the *shejpali* system of Maharashtra, where there are several operational implications in terms of receiving water applications, sanctioning applications, and then releasing water through gated pipe outlets. The operational implications of the *shejpali* system are such that it has the potential for reform by transferring these functions from the irrigation department to the water users. The same cannot be said about the *warabandi* system of irrigation.

State policy for the formation of WUAs further tended to deepen the effects of agrarian structures and social relations. Field studies show the domination of the WUA decision-making processes by the local village elite (Narain 2003a). A study of the organizational dynamics of the day-to-day functioning of WUAs in a watercourse in a village in the Rohtak district (Narain 2003a) draws attention to how the day-to-day functioning was dominated by three individuals who held positions of power and misused the WUA's financial resources. Other members complained of a lack of access to essential information regarding the functioning of the WUA. The three individuals were further able to evade accountability to other members due to their elite position in the village hierarchy and networks. The study, guided by an ethnographic approach and based on a prolonged period of observation and immersion in the site, found that the three individuals were bound by strong ties of friendship. The study is useful in demonstrating the social embeddedness of collective action shaped by social and power relations. There were conflicts inside the WUA that were socially embedded, i.e., they were reflective of other conflicts in the community. When the WUA was formed, it was done by choosing the eldest member from each *thola,* revealing the socially embedded and patriarchal nature of institutions for collective action.

Another critique of the PIM strategy in Haryana was that it shifted the responsibility for irrigation system management to the farmers at the tertiary level when the main management challenges, such as poor functioning and maintenance and water thefts, were situated at levels above the outlet (Narain 2003a). It was argued that if irrigation reforms were to be meaningful in the context of Haryana, such reforms would have to be carried out above the outlet, at the level of the main system, where the more critical management challenges persisted. This led to explicit demands for reform of the main system, i.e., at the main canal and the distributary level rather than at the outlet or tertiary level. This drew attention to earlier debates in canal irrigation reforms about managing blind spots in canal irrigation (Wade and Chambers 1980).

Green Revolution: The Global Policy and Institutional Context

The term 'green revolution' is used to refer to the increase in cereal production experienced in a few developing countries as a result of the change in agricultural technology during the 1960s and 1970s (Parayil 1992). A discussion on the green revolution is central to that of agrifood systems in Haryana because the state was one of the cradles of the green revolution in the country and has remained a major contributor to India's food basket. The introduction of the green revolution lifted Haryana out of the trap of agricultural neglect and stagnation that had been characteristic of the period of colonial rule in the state.

There was an international policy and institutional context within which the green revolution technology was introduced in India. Prior to the green revolution, Indian agriculture was characterized by subsistence farming and rudimentary markets for agriculture (Parayil 1992). A stagnation in agricultural productivity culminated in a near-famine situation in the 1960s. The imperatives of feeding one-fourth of the global population on just one-sixteenth of the land area presented an important challenge.

Agriculture had languished during the colonial period, characterized by disastrous droughts, relatively little technological change, and sluggish land reforms (Shetty et al. 2014). Modern agricultural technology was used during the British administration mainly to boost the production of exportable cash crops such as cotton, tea, coffee, jute, rubber, and spices. India was regularly struck by famine, the most acute of which was the Bengal famine of 1943. Against this backdrop, food security emerged as a dominant agenda for independent India. The first five-year plan strongly emphasized agricultural rehabilitation along with irrigation, fisheries, animal husbandry, and market development. Due to widespread drought from 1965 to 1966, India imported food grains from the United States under the PL-480 scheme. Unexpectedly, however, the United States decided not to export wheat to India due to domestic circumstances. This incident paved the way for launching a green revolution in India.

This was also the time when semi-dwarf varieties had already been developed in China (for rice) and Mexico (for wheat). India's first HYV of rice, known as Jaya, was introduced in 1968. In wheat, Lerma Rojo 64 A and Sonora 64 were introduced directly from Mexico. Later two more varieties, Sharbati Sonara and Kalyan Sona, were released for cultivation. The introduction of these HYVs of seeds, along with appropriate government policies providing essential inputs, market facilities, and credit, sought to revolutionize Indian agriculture.

The introduction and widespread adoption of green revolution technology in India had three distinct phases (Parayil 1992). The first phase (1952–1965) was characterized by the development of a new and indigenous agricultural research system. In 1952, India signed its first contract with the United States Agency for International Development (USAID) university. In the mid-1950s, the Indian government sought the support of the Ford and

Rockefeller Foundation and USAID to establish a high-quality graduate school at the Indian Agricultural Research Institute (IARI) in New Delhi.

The second phase (1962–1967) was marked by the overhaul and reform of the agricultural bureaucracy in India to facilitate the diffusion of HYVs in the domestic agrarian system. This required a reform of the agricultural institutions and commodity committees that had been established by the colonial administration. In 1962, Indian scientists successfully tested an HYV of Mexican wheat under Indian environmental conditions. An HYV of rice was tested in 1964. These HYVs were introduced for the first time in the Indian market during the 1965–1966 growing season.

The third phase (1965–1975) was marked by the change in agricultural practice as a result of the introduction of HYVs. Farmers began to adopt the new technology extensively, beginning with the 1965–1966 growing season. Agricultural productivity increased steadily until 1975 (Parayil 1992). Thereafter, the increase in productivity began to level off. By this time, farmers in different parts of India had achieved a two- to three-fold increase in agricultural yields compared to the 1965 base. Agricultural productivity began to register considerable growth again in the mid-1980s, which some analysts attribute to a second green revolution.

Green Revolution in Haryana

Within the state of Haryana, the period of the green revolution saw a further expansion in the net sown and irrigated areas as well as a change in the cropping pattern. The task of clearing land in the state for agriculture had been initiated in the pre-colonial period, intensified during British rule, and continued until the early 1970s (Kumar and Dangi 2018; Richards et al. 1985). The introduction of the green revolution technology in Haryana influenced the cropping pattern and encouraged a move toward monocropping. However, the green revolution also came to be associated with severe long-term negative environmental consequences, such as a fall in the water table levels and diminishing soil productivity. Besides, it had a limited regional spread in the state, being confined mainly to the districts of Kurukshetra and Karnal.

The net sown area in Haryana was approximately 78% in 1966–1967, and it increased to over 81% in 1990–1991 (Singh 2000). During the same period, cropping intensification increased with a significant expansion in the areas that had more than one crop per year; in the 30 years between 1950–1951 to 1980–1981, this increased from 11% to 42%, and again to 53.6% in 1990–1991. Given the legacy of protective irrigation (discussed earlier in this study), this increase in cropping intensities did not agree with the low intensities of the protective irrigation systems that were in place as introduced during British rule. As land use intensity increased, the area of land under irrigation also increased – from approximately 61% in 1984–1985 to 73% in 1990–1991 (Singh 2000).

A significant impact of the new agricultural technology on the state was a change in the cropping pattern. In this context, new agricultural technology implies the use of HYVs of seeds, timely irrigation, and application of pesticides and chemical fertilizers. A shift in the cropping pattern was observed for both *Kharif* and *Rabi* crops. Monoculture emerged as the dominant cropping system.

For instance, during *Kharif*, there was a shift away from jowar (sorghum) and bajra (pearl millet) toward rice. Likewise, wheat replaced barley and gram during *Rabi*. This change in the cropping pattern is attributed mainly to an expansion of irrigation facilities (Singh 2000), though farmers had also developed a preference for HYV seeds and more remunerative crops such as wheat and rice. Nonetheless, barley and gram continued to be grown in the rainfed areas of the state.

Overall, following the introduction of the green revolution technology, rice (*Oryza sativa*) and wheat (*Triticum*) replaced pulses, bajra, and jowar (*syricum*) as dominant food crops, while cotton (*Gossypium*) emerged as the key cash crop. The yields of rice and wheat in the state increased considerably from 1965–1966 to 1992–1993 (Singh 2000). For instance, the Gurgaon district recorded the highest compound growth rate of 5.22% for wheat during 1986–1995.

In recent years, however, the two dominant crops, rice and wheat, have faced severe constraints in terms of their sustainable productivity (Sharma and Mukhopadhyay 1999). The major challenges to rice productivity are inadequate irrigation due to a decline in the water table and poor discharge of tube wells; inadequacy of canal water supplies; poor quality of groundwater; and increasing problems of salinity and alkalinity. Other challenges to rice productivity are declining soil fertility due to the depletion of major- and micro-nutrients (nitrogen, phosphorus, and zinc), which is attributed to the continuous rice–wheat cropping system; deterioration of the physicochemical soil conditions due to tillage and puddling; imbalanced use of fertilizers; delayed and prolonged transplanting of rice; excessive cultivation of basmati rice (which is susceptible to diseases and insect pests but cultivated nevertheless as it is remunerative); heavy losses due to diseases, insect and pests such as bacterial leaf blight, stem-rot, false smut, leaf folder, and stem-borer.

The major constraints to the productivity of wheat come from the late plantation of wheat (10%–15% until December 25; 40% after December 25); the presence of weeds; reduced soil fertility with regard to both major- and micro-nutrients and soil organic matter; increase in soil salinity/alkalinity, especially in the western districts; and the rising problem of disease in popular varieties such as HD2329 and HD 2285. In addition, rust and heavy incidence of leaf blight are also identified as other constraints hampering the productivity of the crop.

Over time, the green revolution technology in Haryana has come to be associated with serious negative environmental effects. Large parts of the land are affected by desertification, soil salinity, waterlogging, floods, and droughts due to deforestation-induced excessive soil erosion resulting from inappropriate agricultural practices. Besides, in India, the use of agrochemical fertilizers is the highest in Haryana (Singh 2000). There is an imbalance in the nitrogen, phosphorus, and potassium (NPK) consumption ratio in rice and wheat crops. While the use of potassium is also lower in this region, a clear trend has been observed in the accumulation of nitrates in groundwater, reaching toxic levels.

A major challenge has been the declining water table level, given the over-exploitation of groundwater. As much as 95%–98% of the areas under rice and wheat cultivated have to be irrigated, and irrigation from groundwater accounts for about 60%–65% of the total irrigation requirement, and the remaining is met through canals (Singh 2000). This excessive exploitation of groundwater has had a severe impact on the groundwater levels. Several districts in the rice–wheat growing regions have recorded a decline in the water table in the range of 3–10 meters. For instance, the water table has dropped by 10 meters in Kurukshetra, 5 meters in Karnal and Panipat, and 3 meters in Ambala, Yamunanagar, and Kaithal (Singh 2000).

A consistent decline in the groundwater table poses serious challenges to the sustainability of the green revolution. In Haryana, the impact of groundwater depletion is apparent in high tube well–density districts such as Panipat and low tube well–density districts such as Mahendragarh (Banerji and Meenakshi u.d.). This is attributable to the increased popularity of paddy and, to a certain extent, sugarcane, both of which have seen significant expansion in acreage since the 1980s. The popularity of the wheat–paddy combination is largely due to the credible output-price support system prevalent in the state through which the government is committed to purchasing grains that are offered to it at the minimum support price. The cultivation of the post-monsoon water-intensive paddy crop has also been spurred on by the availability of subsidies for tube wells, subsidized diesel, and flat-rate electricity prices.
The prevailing argument regarding the issue of groundwater depletion is focused on the increasing adoption of the wheat–paddy combination resulting from state policies that support minimum prices and various subsidies. However, in this discussion, the technological context of irrigation has been left unexplored and ignored. The boom in tube well irrigation and the subsequent fall in water table levels must be seen against the backdrop of the protective irrigation systems that were introduced in the state by the British designed to meet a fraction of the water requirements for crops and not aligned with the demands of the green revolution technology.

Joshi and Tyagi (1991) compared the sustainability of the green revolution period (1972–1973 to 1979–1980) with that of the post–green revolution period (1980–1981 to 1987–1988) and found that in areas endowed with good-quality groundwater, such as the districts of Karnal, Kurukshetra, and parts of Jind, the resource was being over-exploited. On the other hand, regions with poor-quality groundwater, such as the districts of Hissar, Rohtak, and other parts of Jind, reported an overall rise in the water table rather than excessive groundwater extraction. Both these scenarios are undesirable for the sustainability of agriculture. Rice–wheat rotation is generally followed in good water quality zones, whereas cotton–wheat is practiced in most of the poor-quality groundwater areas. Sugarcane is a common crop in both instances.

In their study, Joshi and Tyagi (1991) focused on four crops: rice, wheat, cotton, and sugarcane. They examined the compound rates of growth of production, area, and yield for the sample crops and concluded that in the majority of the districts of the state, the growth rate of production had

had slowed down during the post–green revolution period; the rates of yield had either become stagnant, negative, or insignificant. Their study further showed that crop substitution and reclamation of degraded soils contributed to the increase in the production of rice and wheat during the post–green revolution period; yet this contribution was rather slow and inadequate to compensate for the fall in the growth rate since the green revolution period, that is, the period of the green revolution associated with increases in agricultural growth rate.

In general, the production and profitability of rice and wheat shrunk in the post–green revolution period. Similarly, the acreage of cotton declined, and sugarcane did not show any encouraging results either. Deteriorating soil health and stagnating technological innovation since 1966 were identified as the key constraints impacting production. Although fertilizer consumption had increased and irrigated areas expanded, the rates of growth of yield had slowed down. High private profitability of rice, along with state incentives on inputs and better output support prices, were responsible for acreage gains, that is, increases in the area under rice cultivation, in the Punjab and Haryana.

Within Haryana, Karnal and Kurukshetra districts were dominated by tube well irrigation, and the area under tube well irrigation increased in both these districts over time (Joshi and Tyagi 1991). Since Jind, Hissar, and Rohtak had poor-quality groundwater, canal irrigation was the predominant source of irrigation in these districts. The overexploitation of groundwater in Karnal and Kurukshetra (as previously discussed) resulted in a drop in groundwater levels. The irrigation requirement of rice for this region is 130 cm/ha, while that of wheat is about four times less. Therefore, rice accounts for approximately 35% of the total irrigation requirement in Haryana (Joshi and Tyagi 1991). The canal seepage in these districts offsets some of these effects; otherwise, the water table level would have been even lower. In Karnal, the water table level fell from 4.8 meters in 1974 to 7.7 meters in 1989; in Kurukshetra, it fell from 7 meters to 10.7 meters during the same period.

As a result of the economic and ecological factors described above, the state experienced fatigue from the green revolution (Shetty et al. 2014). Consequently, the regions where the benefits of the green revolution were harnessed in abundance faced the challenges of land degradation, yield plateauing, and a deceleration of their compound growth rate. At the same time, there was a regional imbalance in the spread of the green revolution in the state; it remained confined to Karnal, Kurukshetra, and their neighborhood, where the effects on agrarian relations and the agricultural wage rate were also more pronounced than elsewhere (Bhalla 1976).

Climate Change and Agriculture in Haryana

An important consequence of the introduction of the green revolution technology was a shift toward the cultivation of wheat and paddy. As high as 95% of the total cultivable area came under the rice–wheat cropping system (Sendhil et al. 2015). The share of rice in the total food grain production of Haryana increased sharply from 50% in 1966–1967 to more than 90% (Sendhil et al. 2015). In the preceding sections of this study, we have highlighted the factors that have led to stagnant or plateauing yields of these crops in recent years. In addition, several recent studies have emphasized the adverse impacts of climate change on agricultural production.

Rice, a *Kharif* crop, is expected to be impacted more by the variability in rainfall, while wheat, which is grown in *Rabi*, is more likely to be affected by random variations in minimum temperature. Wheat is also likely to be affected by climate change–induced terminal heat stress, while rice will be affected by temperature and water availability (Sendhil et al. 2015). In general, changes in solar radiation, temperature, relative humidity, and precipitation have been shown to affect crop yield, crop mix, cropping system, scheduling of field operations, grain moisture content, and, subsequently, farmer income. In addition, increasing rainfall and its erratic pattern will lead to more cloudy days, causing further yield reduction.

Aggarwal (2008) analyzed the historical trend in rice and wheat yields in the Indo-Gangetic plains using archival data, fertility experiments coupled with conventional field experiments, and crop simulation models and found that rice yields over the last three decades show a declining trend, which may be partly related to the gradual change in weather conditions in the last two decades. Similarly, Kumar et al. (2019) found that an increase in rainfall and extreme temperatures negatively impacted rice production in Haryana. They also confirmed that an increase in maximum temperature was detrimental to rice and wheat.

Farmers in Haryana are experiencing and are aware of a changing climate in terms of fluctuating temperatures and increasingly erratic rainfall. In their study, Aryal et al. (2018) identified excess heat at critical stages of crop growth, depletion of groundwater, waterlogging and excess moisture, and strong wind and storms as major climate risks. Erratic rainfall has had a severe impact on wheat production. During the harvest period, rainfall can cause waterlogging in the fields, which loosens the roots of wheat plants. This results in significant production loss as the roots are no longer able to support full growth (Aryal et al. 2018).

Institutional support for climate-smart agriculture in Haryana started in 2002 in cooperation with the rice–wheat consortium and the Climate Change, Agriculture and Food Security (CCAFS) program, an initiative of the Consultative Group on International Agricultural Research (CGIAR). Haryana suffered from untimely excess rainfall in 2014–2015 during the wheat production season, which damaged over 0.5 mha of the wheat crop (Aryal et al. 2020). The Haryana government spent approximately INR 11 billion to compensate the farmers affected that year.

Aryal et al. (2020) have argued that a wheat production system that can reduce the vulnerability of wheat to damage caused by climatic risks can significantly reduce the farmers' loss as well as the government's economic burden. They also found that in Haryana, many farmers already followed the conservation agriculture–based wheat system (CAW) [**7**], which incurred less damage from untimely excess rainfall compared to the conventional tillage-based wheat production systems (CTW). Ironically, during the extreme climate event in 2014–2015, when the Haryana government compensated only those farmers whose crop yield loss was greater than 30%, it ended up disincentivizing farmers using CAW, as their losses were less than those using conventional practices. Therefore, Aryal et al. (2020) argue that compensation policies should also factor in wheat production practices rather than focus only on the percentage of actual loss. Their study concluded that learning and communication were the most crucial factors enabling CAW adoption. Therefore, providing support to agricultural education programs for farmers should be a priority for policymakers beyond focusing solely on input subsidies and credit.

Designing an appropriate strategy to communicate scientific evidence to farmers, reshaping compensation policies, and strengthening local extension institutions are essential in enabling farmers to adapt to the negative effects of climate change on crop production. At the local level, farmer-to-farmer communication was found to be a critical factor in promoting technology adoption. CAW was adopted as a climate risk coping measure by farmers who learned climate change adaptation through their own experience and the experience of their neighbors. An earlier study (Aryal et al. 2016) compared wheat yield in good and bad years and found that CAW performed better than CTW.

during both periods. Since farm mechanization is high in Haryana, the study found that CAW can cope better than CTW in extreme rainfall conditions during the wheat season.
In a study of four villages in the Sohna district of Gurgaon, farmers reported a declining rainfall trend after 1982–1983, as well as the disappearance of the monsoon period (Narain 2023). Earlier, the rainfall was spread evenly across the four monsoon months from July to October. Now, farmers report only sudden and sporadic rains. Changing climatic patterns, particularly the current pattern of shorter winters and longer summers, are said to affect the viability of the wheat crop. According to Narain (2023), farmers complained that they needed a longer winter period for the wheat crop to mature. Similarly, in the *Rabi* harvest season of 2023, untimely rains caused the wheat crop to wilt. This meant a higher wage rate for labor engaged in harvesting wheat; it went up from 8 *mann* for harvesting one acre of wheat crop to 10 *mann* for this cycle [**8**]. This way, ill-timed rains played a role in raising the cost of the harvest of the crop.

Overall, climate change has a significant impact on agriculture, yet, it affects landlords and tenants differently, creating a differential vulnerability between them. Many landowners give land out to till on a contractual arrangement called *kann-batai*, wherein the tenant pays a pre-agreed amount to the landowner upfront. If the crop fails due to climate vagaries, the tenant bears the loss (Narain et al. 2016). Further, the geographical location of agricultural fields plays a critical role in shaping the differential vulnerability of tillers. For instance, lands located in low-lying areas or a depression are vulnerable to being flooded in times of high rainfall (Narain et al. 2016).

A parallel body of literature has emerged on the impact of climate change on agriculture in peri-urban contexts. This literature focuses on how urbanization and climate change impact peri-urban agriculture. As flagged earlier, farmers in peri-urban areas such as Gurgaon have already complained about shorter winters, longer summers, declining frequency of rainfall, , and the disappearance of the *chaumasa* (four-month monsoon period) (Narain et al. 2016; Narain and Singh 2017) as a result of climate change. In the Sadrana village of Gurgaon, farmhouses popping up in the vicinity of agricultural fields intensified competition for groundwater; small and marginal farmers who could not afford the high costs of groundwater extraction were left chasing the water table. They responded by either leaving the land fallow or using sprinkler irrigation systems, given that the soil was sandy and the terrain was undulating (Narain 2014).

Peri-urbanization and the changing and emerging rural–urban flows of water also have the potential to impact peri-urban agriculture. In the Budhera village of peri-urban Gurgaon, one impact of the in-flowing wastewater canal that carried the urban waste of Gurgaon was that farmers started cultivating wheat and paddy. Narain and Singh (2017) found elaborate norms of cooperation among irrigators in using wastewater; they cooperated by taking turns to irrigate. They contributed labor and capital for the construction of furrows for carrying wastewater to the fields. The reliance on wastewater as a source of irrigation has increased with changes in precipitation patterns. Irrigators wait for the monsoon for paddy irrigation, and if there is no rain or deficient rain when irrigation is needed, they resort to wastewater irrigation. A wide variety of technologies have been used to appropriate wastewater for irrigation: a pipe outlet at the bed of the canal, diesel and electric pump sets, and pump sets attached to tractors.

There is considerable evidence that the state's farmers have the potential to self-organize for collective action in response to adapt to the combined effects of urbanization and climate change (Narain and Singh 2017; Mishra and Narain 2018). In Budhera, this is evident through the effort pooled to provide labor for digging furrows to transport water from a wastewater canal to the fields. Irrigators install a pipe outlet along the banks of a wastewater canal to collect wastewater. For the use of this service, they pay a nominal fee to the irrigation department annually. However, the wastewater is used by a large number of irrigators, as much as one km away from the wastewater canal and the pipe outlet. These farmers contribute labor to dig a furrow and cooperate in taking turns to irrigate from the wastewater canal. It is important to note that this practice is followed among irrigators and not necessarily among landowners.

The basis of cooperation here is physical proximity rather than a unit of social organization such as caste. These cooperative initiatives are legitimized based on *bhaibandi* (brotherhood), which denotes a sense of cooperation and collective identity. It is somewhat akin to the notion of *bhaichaara*, which provides a legitimization to time exchanges under the *warabandi* system (Narain 2003a, 2003b). In Budhera, the collective response in terms of cooperating in the use of wastewater is a response to the absence of an irrigation canal serving the region, the presence of saline groundwater, and changing precipitation patterns.

Bhaichaara and *bhaibandi* provide examples of social capital and evidence of collective responses in adapting to regimes of water scarcity, which may be created either by design, as in the case of the protective irrigation systems, exemplified in the Haryana case by *warabandi*, or by the combines effects of processes such as urbanization and climate change. Though Haryana is not considered a cradle of cooperation or collective movements like Gujarat and Maharashtra, the prevalence of informal norms of cooperation representing a form of social capital provides a basis to strengthen adaptive capacity. The emergence of such collective forms of self-organization also provides insights into institutional evolution in the agrifood systems of the state.

Public Policy Response and Reduced Vulnerability to COVID-19

The procurement policy of the state government has been criticized for its negative impact on groundwater levels, as discussed in earlier sections of this study. However, this policy played an important role in shielding the state's farmers from the negative effects of the COVID-19 lockdowns [**9**].

A high population density and an inadequate health infrastructure necessitated an early response to the COVID-19 pandemic in India (Narayanan 2020). The central government responded by restricting commercial and industrial activity, curtailing the movement of people and goods deemed non-essential. Subsequent interventions allowed some exceptions for agricultural activities, marketing of agricultural goods, custom hiring and inter-state movement of agricultural equipment, and manufacturing of agricultural inputs. In subsequent revisions of nationwide measures during April and May 2020, these exemptions were maintained and further supported by opening up, among others, agricultural input stores, machinery repair shops, and agri-businesses. The movement of people, including agricultural laborers, however, remained severely constrained. Inter-district travel, other than for emergency purposes, was prohibited, and public transport facilities remained shut until May 2020. It is important to note that these restrictions were imposed at a time when the *Rabi* crop was just about ready for harvest in North India. These restrictions thus presented important challenges for millions of smallholder farmers in the region about to harvest their winter crops. In many states, licensed market yards, or *mandi*s, where the bulk of the produce is sold, remained closed during the initial weeks of the pandemic (Narayanan 2020). Interstate movement of transport vehicles and agricultural harvest equipment was hampered due to delays from mandatory border checks; lack of personal protective equipment to abide by social distancing guidelines; local norms; fears; and misinformation about COVID-19. Several seasonal and migrant laborers across the country traveled back to their home states.

With restrictions on the inter-district movement of people and resources, harvest operations became directly dependent on the supply of labor, equipment, and inputs at the local level and on the state's pre-existing agricultural marketing arrangements. The government of Haryana responded proactively to the situation by leveraging its market infrastructure and agent network to pursue a staggered procurement plan during the lockdown. This greatly eased congestion and the strain on the state's resources (Ceballos et al. 2020). Wheat procurement at *mandi*s was delayed, with only 100 farmers entering the *mandi* per day, divided over one shift each in the morning and afternoon. Nonetheless, efforts were made to reach all farmers through existing databases and the commission agent network. The number of *mandi*s increased from 477 to 2,000, and nearly 500,000 farmers (approximately 61% of the farmers) who had registered for the procurement system were able to sell their produce through this mechanism.

Ceballos et al. (2020) did a comparative study of 1,275 farmers growing wheat in Haryana and 240 farmers growing black gram in Odisha during the COVID-19 period. Farmers in both states had adjusted the timing of their harvest. In Haryana, farmers reported harvesting earlier (11%) or later (32%) than normal. Since the harvest window only began in April, as it typically does, wheat farmers could not harvest and sell their crops before the lockdown was imposed. However, key informant interview (KIIs) respondents in the study reported that since the wheat crop had reached maturity later than usual, and it is a hardy crop, the timing of the harvest could be adapted to the availability of inputs and procurement, limiting economic losses. However, 41% of the farmers in Haryana reported having to spend more on harvest than usual due to the lockdown, with 25% of the farmers incurring higher labor costs and 23% spending more on machinery, likely due to reduced availability.

During the lockdown, labor would have moved back to the home states, including Odisha. In principle, this would have increased wages in Haryana (due to deficit supply) and reduced wages in Odisha (due to surplus supply) (Ceballos et al. 2020). In contrast, the study found that farmers did not spend more on wages but rather on transport, food, and accommodation arrangements for their laborers during the lockdown. In addition, farmers in Haryana had the option of shifting to mechanized alternatives, which were not available to farmers in Odisha. In both states, most farmers (61% and 74%, respectively) were not able to sell their produce immediately upon harvest and had to store it for future consumption or sale. In Haryana, post-harvest losses related to these delays remained limited: 85% of the sample respondents reported no storage-related losses. The KIIs conducted during the study indicated that this was due to the effective storage facilities in Haryana that allowed farmers to safeguard their produce. None of the respondents had to sell the produce below the minimum support prices.

The study found that, in Haryana, overall, the mechanized farming system and existing public procurement institutions, which helped the state government implement a timely and sound procurement process during the lockdown, prevented widespread losses in farm income. On the other hand, the absence of such institutions, combined with labor-intensive practices in Odisha, resulted in crop and income losses for many farmers in the state.

CONCLUSION

When we look at the evolution of policy and institutions in the agrifood systems of Haryana across the colonial and postcolonial periods, we notice elements of continuity as well as discontinuity. The elements of continuity are seen mainly in the expansion of arable land and irrigated areas. The construction of canal irrigation systems started in the state in medieval times. During British rule, it evolved into the construction of protective irrigation systems. The philosophy of protective irrigation continued to guide the expansion of irrigated areas in the postcolonial period as well. However, the element of discontinuity is reflected in how the protective irrigation systems came to be conceptualized.

The meaning of protective irrigation evolved over time. During the colonial period, protective irrigation emerged as a strategy to secure colonial rule by preventing famine, stalling social and political unrest, and securing the production of cash crops. The rationale for the construction of protective irrigation systems was strongly influenced by the recommendations of the famine and irrigation commissions, both of which proposed the construction of protective irrigation systems as a means of preventing famine. In the postcolonial period, protective irrigation came to be understood as a form of irrigation with specific organizational and technical characteristics, mainly suited to drought-prone areas. Its technical characteristics were represented by the intended irrigation intensities, capacity factors, and allowances. Until the end of the British period, these systems worked more or less as designed. The low irrigation intensities that were the basis of their design matched the cropping choices of the farmers.

A massive expansion of arable land occurred during the colonial period, though this exercise had already begun during the medieval period. This expansion continued well into the postcolonial period of planned economic development and illustrates yet another element of continuity between colonial and postcolonial periods. However, by the 1970s, it was no longer possible to expand arable land, and the emphasis thus shifted from expanding cultivable land to improving agricultural productivity. This shift in emphasis represents an element of discontinuity in state policies between the colonial and postcolonial periods. Another significant element of discontinuity was the shift from cash crops of the British period to food grains post-independence. Both these shifts were necessitated by factors such as widespread famines and the massive expansion of arable areas that had occurred during British rule.

A strong element of discontinuity is also evident in the working of the canal irrigation systems. Designed similar to the protective irrigation systems, these systems worked as intended during the colonial period. However, in the postcolonial period, their low irrigation intensities proved to be inadequate. With the introduction of HYV seeds and the policy of minimum support prices for food grains, farmers wanted to increase the production of wheat and paddy. A switch to monocropping was a significant effect of the introduction of the new agricultural technology; as much as 95% of the net sown area in the state had a wheat–paddy combination. Farmers wanted to pursue productive irrigation, seeking to maximize the production per unit of land, while protective irrigation sought to maximize production per unit of water.

This conflict between the objectives of the farmers in response to the combined effects of the introduction of the new agricultural technology and the policies for input subsidies and minimum support prices led to the emergence of new technological and institutional responses in the state's agrifood systems. The farmers' technological responses ranged from the digging of tube wells and the use of rice shoots to water thefts along the canal. Their institutional responses took the form of innovative practices such as time exchanges. Time exchanges represent institutional evolution in the agrifood systems of Haryana at the interface of multiple legal repertoires. They are shaped by an intersection of both statutory law (which defines water rights in terms of the time for taking water sanctioned by the Haryana Canal and Drainage Act of 1974) and normative systems (such as those of *bhaichaara*, which have a strong social sanction).

While considering the policy and institutional evolution of the agrifood systems of Haryana, or for that matter, anywhere else in South Asia, it is necessary to pay attention to the technological context within which such evolution happens. This study adopted a sociotechnical lens to explore the institutional evolution in Haryana's agrifood systems, drawing attention to the relationship between technology (irrigation infrastructure) and the institutions (forms of water allocation and distribution) (see also Kloezen and Mollinga 1992).

The postcolonial literature on agrifood systems in the state has been dominated by discourses focused on the green revolution. The early narratives on the green revolution flag its impacts on increasing food security in the state; the latter narratives point to the consequent diminishing of soil productivity and the declining water table levels. The increase in the productivity of rice and wheat reached a plateau, the effects of which were further aggravated by climate change.
Haryana emerged as a major cradle of the green revolution and an important contributor to the nation's food security, largely in response to the shift toward monocropping – i.e., the cultivation of wheat in *Rabi* (winter) season and paddy in the *Kharif* (monsoon) season. Though the procurement policy of the state is often blamed for encouraging farmers to grow water-intensive crops, thereby aggravating the stress on the groundwater table, it has been an important factor, along with the mechanized nature of the state's agriculture, in reducing the vulnerability of farm incomes to the effects of the COVID-19 pandemic.

Haryana is currently in the midst of a structural transformation. From being the cradle of the green revolution, it is now being repositioned as a major center for industry, outsourcing, and real estate. This has implications for the nature of agriculture itself and necessitates a stronger focus on the dynamics and processes characterizing peri-urban agriculture in the years to come. This will include examining the implications of changing access to water and land; the emerging norms of cooperation or conflict around land and water; the diversity in the sources of irrigation; and the emergence of new institutional arrangements in peri-urban agriculture.

ENDNOTES

1. A duty is a technical term in irrigation that refers to the area that can be irrigated with a unit volume of irrigation water. It is expressed in hectare/ cubic metre seconds.
2. For detailed accounts of the *warabandi* irrigation in Pakistan, see Merrey 1986a, 1986b; Wahaj 2001. See also Reidinger 1974 and Bandaragoda 1998.
3. In December 2023, the exchange rate for USD 1 was approximately INR 80.
4. A rice shoot is a pipe outlet that is temporarily sanctioned for the irrigation of paddy, as it requires additional water than provided by the existing allocations. After the *kharif* irrigation is over, the rice shoot is removed (Narain 2003a, b)..
5. See Merrey 1986 a, 1986b; Wahaj 2001.
6. See, for example, Groenfeldt 2000; Mollinga 1998.
7. CAW is based on the principle of minimum soil disturbance, continuous ground cover, and appropriate crop rotation. It provides an alternative to the conventional system to enhance the crop's resilience against climate variability through better adaptation to climate change and reduction of GHG emissions, e.g., reducing air pollution by eliminating residue burning.
8. 1 *mann* is approximately 40 kgs.
9. On the evening of 24 March 2020, the Government of India ordered a nation-wide lockdown for 21 days. Some state governments subsequently extended the lock down to May 1, 2020. A nationwide extension of the lockdown was subsequently made until 17 May. On 17 May, the National Disaster Management Authority (NDMA) further extended the lockdown until 31 May https://en.wikipedia.org/wiki/COVID-19_lockdown_in_India, accessed on December 13, 2023)

REFERENCES

- Amrohi, K.K. 2013. Land revenue policy in the south-eastern Punjab under colonial rule. *International Journal of Management and Social Sciences Research* 2(5): 15–22.
- Anderson, T.L.; Snyder, P. 1997. *Water markets: Priming the invisible pump*. Washington D.C.: Cato Institute.
- Aryal, J.P.; Sapkota, T.B.; Khurana, R.; Khatri-Chhetri, A.; Rahut, D.B.; Jat, M.L. 2020. Climate change and agriculture in South Asia: Adaptation options in smallholder production systems. *Environment, Development and Sustainability* 22(6): 5045–5075.
- Aryal, J.P.; Jat, M.L.; Sapkota, T.B.; Rahut, D.B.; Rai, M.; Jat, H.S.; Sharma, P.C.; Stirling, C. 2018. Learning adaptation to climate change from past climate extremes: Evidence from recent climate extremes in Haryana, India. *International Journal of Climate Change Strategies and Management* 12(1): 128–146.
- Aryal, J. P., Farnworth, C. R., Khurana, R., Ray, S., & Sapkota, T. B. (2014). Gender dimensions of climate change adaptation through climate smart agricultural practices in India. *Innovation in Indian Agriculture: Ways Forward. New Delhi: Institute of Economic Growth (IEG), New Delhi, and International Food Policy Research Institute (IFPRI), Washington, DC.*

- Bandaragoda, D.J. 1998. *Design and practice of water allocation rules: Lessons from warabandi in Pakistan's Punjab*. Colombo: International Water Management Institute (IWMI). (Research Report 17). https://hdl.handle.net/10535/4304
- Bandaragoda, D.J.; Rehman, S. 1995. *Warabandi in Pakistan's canal irrigation systems: Widening gap between theory and practice*. Colombo: International Water Management Institute (IWMI). (Research Report 7). https://hdl.handle.net/10568/36240
- Banerjee, A.; Meenakshi, J.V. u.d. *Groundwater irrigation in Haryana: Institutions and markets.* 11 pp. https://econpapers.repec.org/paper/esswpaper/id_3a899.htm
- Bauer, C. J. 1997. Bringing water markets down to earth: The political economy of water rights in Chile, 1976–1995. *World Development* 25(5): 639–656.
- Berkoff, D.J.W. 1990. Irrigation Management on the Indo-Gangetic Plain. World Bank Technical Paper Number 129. The World Bank, Washington, D.C., USA.
- Bhalla, S. 1976. New relations of production in Haryana agriculture. *Economic & Political Weekly* 11(13): A23–A30. http://www.jstor.org/stable/4364490
- Bolding, A.; Mollinga, P.P.; Van Straaten, K. 1995. Modules for modernisation: Colonial irrigation in India and the technological dimension of agrarian change. *The Journal of Development Studies* 31(6): 805–844.
- Ceballos, F.; Kannan, S.; Kramer, B. 2020. Impacts of a national lockdown on smallholder farmers' income and food security: Empirical evidence from two states in India. *World Development* 136: 105069. https://doi.org/10.1016/j.worlddev.2020.105069
- Dye, T.R. 2013. *Understanding public policy*. New York: Pearson.
- Groenfeldt, D. 2000. Introduction: A global consensus on participatory irrigation management. In: Groenfeldt, D.; Svendsen, D. (eds.) *Case studies in participatory irrigation management*. Washington D.C.: World Bank Institute. pp.1-2.
- Joshi, P.K.; Tyagi, N.K. 1991. Sustainability of existing farming system in Punjab and Haryana: Some issues on groundwater use. *Indian Journal of Agricultural Economics* 46(3): 412–421.
- Jurriens, M.; Landstra, W. 1989. Water distribution: Conflicting objectives of scheme management and farmers. In: Rydzewski, J.R.; Ward, C.F. (eds.) *Irrigation theory and practice*. London: Pentech Press. pp.711–720.
- Jurriens, M.; Wester, P. 1995a. Protective irrigation in India. *International Land Reclamation Institute Annual Report 1994*. Wageningen, Netherlands: International Land Reclamation Institute (ILRI).pp.17–32.
- Jurriens, M.; Wester, P. 1995b. Warabandi revisited: To abandon or to improve a basically sound water delivery scheduling method? *International Land Reclamation Institute Annual Report 96*. Wageningen, Netherlands: International Land Reclamation Institute (ILRI). pp.24–43.
- Jurriens, M.; Mollinga, P.P.; Wester, P. 1996. *Scarcity by design: Protective irrigation in India and Pakistan*. Wageningen, Netherlands: International Land Reclamation Institute (ILRI).

- Jurriens, M. 1993. *Protective irrigation: Essence and implications*. Paper presented at the 15th International Congress on irrigation and drainage, September 4–11, 1993, The Hague, The Netherlands.
- Kloezen, W.; Mollinga, P.P. 1992. Opening closed gates: Recognizing the social nature of irrigation artefacts. In: Diemer, G.; Slabbers, J. (eds.) *Irrigators and engineers*. Amsterdam: Thesis Publishers. pp. 53–63.
- Korten, D.C. 1980. Community organization and rural development: A learning process approach. *Public Administration Review* 40(5): 480–511. http://www.jstor.org/stable/3110204
- Kumar, M.; Dangi, V. 2018. History of agriculture in Haryana. *International Journal of Research and Analytical Reviews* 5(2): 1196–1202.
- Kumar, A.; Singh, J.B.; Sharma, P. 2019. Assessing the climate change impact on rice and wheat production in Uttar Pradesh and Haryana states of India. *Climate Change* 6(21): 75-93.
- Malhotra, S.P. 1988. The warabandi system and its infrastructure. CBIP Publication No.157. Central Board of Irrigation and Power. New Delhi.
- Malhotra, S.P.; Raheja, S.K.; Seckler, D. 1984. A methodology for monitoring the performance of large-scale irrigation systems: A case study of the *warabandi* system of northwest India. *Agricultural Administration* 17(4): 231–259. https://doi.org/10.1016/0309-586X(84)90044-X
- Mollinga, P.P. 2003. *On the waterfront. Water distribution, technology and agrarian change in a South Indian Canal Irrigation System*. Hyderabad: Orient Longman. .
- Merrey, D.J. 1986a. Reorganizing irrigation: Local level management in the Punjab (Pakistan). In: Merrey, D.J.; Wolf, J.M. (eds.) *Irrigation Management in Pakistan: Four Papers*. Digana Village, Sri Lanka: International Irrigation Management Institute (IIMI). (IIMI Research Paper 4). pp.26–43.
- Merrey, D.J. 1986b. The sociology of warabandi: A case study from Pakistan. In: Merrey, D.J.; Wolf, J.M. (eds.) *Irrigation management in Pakistan: Four papers*. Digana Village, Sri Lanka: International Irrigation Management Institute (IIMI). (IIMI Research Paper 4). pp.44–61.
- Mishra, P.; Narain, V. 2018. Urban canals and peri-urban agrarian institutions. *Economic & Political Weekly* 53(37): 51–58.
- Narain, B. 1922. *Indian economic problems. Part 2. Source book for the study of Indian economic problems*. Lahore: The Punjab Printing Works.
- Narain, V. 2023. *An impact assessment and process documentation study*. Gurgaon: Navjyoti India Foundation.
- Narain, V. 2018. *Public policy: A view from the south*. New Delhi: Cambridge University Press.
- Narain, V. 2014. Whose land? whose water? water rights, equity and justice in a peri-urban context. *Local Environment* 19(9): 974–989.
- Narain, V. 2008a. Reform in Indian canal irrigation: Does technology matter? *Water International 33*(1): 33–42. https://doi.org/10.1080/02508060801928059

- Narain, V. 2008b. Warabandi as a sociotechnical system for canal water allocation: Opportunities and challenges for reform. *Water Policy* 10(4): 409–422. https://doi.org/10.2166/wp.2008.057
- Narain, V. 2003a. Institutions, technology and water control: Water users' associations and irrigation management reform in two large-scale systems in India. Orient Longman.
- Narain, V. 2003b. Mediating scarcity by design: Water rights and legal pluralism in protective irrigation. In: *Environmental threats, vulnerability, and adaptation.* New Delhi: The Energy and Resources Institute.
- Narain, V.; Singh, A.K. 2017. Flowing against the current: The socio-technical mediation of water (in)security in periurban Gurgaon, India. *Geoforum* 81(1): 66–75. https://doi.org/10.1016/j.geoforum.2017.02.010
- Narain, V.; Ranjan, P.; Singh, S.; Dewan, A. 2016. Urbanization, climate change, and water security in peri-urban Gurgaon. In: V. Narain and A. Prakash (eds.) *Water security in peri-urban South Asia: Adapting to climate change and urbanization*. New Delhi: Oxford University Press. pp. 75–107.
- Narayanan, S. 2020. Food and agriculture during a pandemic: managing the consequence. *Ideas for India*, March 27, 2020. https://www.ideasforindia.in/topics/agriculture/food-and-agriculture-during-a-pandemic-managing-the-consequences.html (accessed on December 6, 2023).
- North, D.C. 1990. *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Press.
- Ostrom, E. 1990. *Governing the commons: The evolution of institutions for collective action*. Cambridge: Cambridge University Press.
- Parayil, G. 1992. The green revolution in India: A case study of a technological change. *Technology and Culture* 33(4): 737–756.
- Parshad, G. 2018. British land revenue policy in Haryana region. *International Journal of Humanities and Social Sciences* 7(8): 63–71.
- Reidinger, R.B. 1974. Institutional rationing of canal water in northern India: Conflict between traditional patterns and modern needs. *Economic Development and Cultural Change* 23(1): 79–104.
- Richards, J.F.; Hagen, J.R; Haynes, E.S. 1985. Changing land use in Bihar, Punjab, Bihar and Haryana, 1850-1970. *Modern Asian Studies* 19(3): 699–732.
- Sendhil, R.; Rajpal, M; Thimmappa K.; Singh, R.; Sharma, I. 2015. Sensitivity of rice-wheat system yields to climate change: Evidence from Haryana. *Karnataka Journal of Agricultural Economics* 28(5): 797–802.
- Sharma, A. 2016. Haryana: a profile. International Journal in Management and Social Science.4(8): 654-708.
- Sharma, B.D; Mukhopadhyay, S.S. 1999. Land cover and land use: Punjab perspective. In: Proceedings of the International Seminar on Historical perspectives of Land-Use Land Cover Change in South Asia for the study of Global Change, April 11-13, 1999. NPL, New Delhi.
- Shetty, P.K.; Manorama, K; Murugan, M; Hiremath, M.B. 2014. Innovations that shaped Indian agriculture: then and now. *Indian Journal of Science and Technology* 7(8): 1176–1182.

- Singh, M. 2012. Imperialism in action: Colonial land revenue policy and the south-east Punjab of British India. *International Journal of Advanced Research in Management and Social Sciences* 1(6): 30–50.
- Singh, R.B. 2000. Environmental consequences of agricultural development: A case study from the green revolution state of Haryana, India. *Agriculture, Ecosystems & Environment* 82(1–2): 97–103. https://doi.org/10.1016/S0167-8809(00)00219-X
- Stone, I.E. 1980. *Canal irrigation and agrarian change under colonial rule: A study of the U.P. Doab, India 1830-1930.* PhD thesis. Cambridge: University of Cambridge.
- Tilak, M.B.G.; Rajvanshi, B.S. 1991. Operation of irrigation systems in India. In: *The Special Technical Session Proceedings, April 1991, Beijing, China*. New Delhi: International Commission on Irrigation and Drainage. pp.B1–B13.
- Uphoff, N. 1992. *Local institutions and participation for sustainable development*. (Gatekeeper Series 31). London: International Institute for Environment and Development.
- van Halsema, G.E. 2002. *Trial & re-trial: The evolution of irrigation modernisation in NWFP, Pakistan*. PhD thesis. Wageningen: Wageningen University.
- von Benda-Beckmann, F. 2001. Between free riders and free raiders: Property rights and soil degradation in context. In Heerink, N.; van Keulen, H.; Kuiper, M. (eds.) *Economic policy and sustainable land use: Recent advances in quantitative analysis for developing countries*. Heidelberg: Physica-Verlag. pp.293–316.
- Wade, R.; Chambers, R. 1980. Managing the main system: canal irrigation's blind spot. *Economic & Political Weekly* 15(39): A107–A112.
- Wahaj, R. 2001. *Farmers actions and improvements in irrigation performance below the Mogha: How farmers manage water scarcity and abundance in a large scale irrigation system in South-Eastern Punjab, Pakistan*. PhD thesis. Wageningen: Wageningen University.
- Whitcombe, E. 1983. Irrigation. In: Kumar, D.; Habib, I. (eds.) *The Cambridge economic history of India* (Vol 2). Hyderabad: Orient Blackswan. pp.677–736.
- Wiener, A. (1976). The World Food Situation and Irrigation Program. *ICID Bulletin, January*.

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