Environ Dev Sustain (2009) 11:751–763
DOI 10.1007/s10668-008-9141-8

Rice–wheat cropping cycle in Punjab: a comparative analysis of sustainability status in different irrigation systems

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Received: 17 May 2006 / Accepted: 21 January 2008 / Published online: 28 February 2008

Abstract There is a general contention among scholars that first, wheat–paddy cropping pattern is largely responsible for declining ground water table in Punjab and secondly, that the wheat–paddy cropping system is becoming unsustainable over time as the yield levels of these two major crops are stagnating. However, the existing evidences do not throw adequate insight into the stage of groundwater depletion during which the wheat–paddy cycle becomes unsustainable. The paper strengthens the existing empirical base of sustainability status of this cropping cycle in Punjab. A comparison of irrigation systems in terms of both trends in yield and stability for wheat and paddy has been attempted to arrive at a holistic appraisal of sustainability aspects of crop specialization in Punjab. It is observed that the canal dependent irrigation system has performed better as compared to the overexploited groundwater irrigation system in terms of most of the parameters used in the study.

Keywords Cropping pattern · Groundwater · Instability · Irrigation systems · Productivity · Punjab

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1 Introduction

Development and natural resource depletion are phenomena that are closely related. Scholars maintain that development with growth as its major objective cannot be sustainable as natural resources are finite (Costanza and Daly 1992). This problem becomes particularly acute in developing countries where population density and growth remain at very high levels (Crosson 1990). It is argued that land and water resources would tend to be over-utilized in a manner that is unsustainable in circumstances where the returns to these resources are very high (Chadha et al. 2004). The case of Punjab agriculture, where in recent years, a substantial proportion of agricultural area has come under wheat–paddy cropping pattern is a case in point.

Sustainability has remained a popular but an elusive concept particularly when it comes to its application to empirical evidences. The dependence of Punjab on groundwater through tube-well irrigation is increasing over the years (Sidhu et al. 1999). There is a general agreement among scholars that firstly, wheat–paddy cropping pattern is largely responsible for declining ground water table in Punjab (Johl 1986; Prihar et al. 1990; Singh 1991; Singh 1992) and secondly, that the wheat–paddy cropping system is becoming unsustainable over time as the yield levels of these two major crops are stagnating (Kumar et al. 1998; Sidhu and Singh 2003). However, the existing evidence does not throw adequate insight into the stage of groundwater depletion during which the wheat–paddy cycle becomes unsustainable.

Stability of crop yield is an important aspect that influences cropping pattern; it is also a manifestation of the capacity of the agro-eco-system to achieve high levels of renewal (Conway 1986; Redclift 1992). It is one of the basic components of a sustainable agro system 'which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide opportunities for the next generation in the short and in the long term' (Chambers and Conway 1992). Conway (1986) gives a technical definition of agricultural sustainability as "the ability of a system to maintain its productivity when subjected to stress or shock", where the former is 'a regular, sometimes continuous, relatively small and predictable disturbance. For example the effect of growing soil salinity or indebtness', and the latter is 'an irregular infrequent, relatively large and unpredictable disturbance, such as caused by a rare draught or flood or a new pest'. Jodha (1991) treats sustainability as a characteristic of the agricultural system: 'it is the ability of the system to maintain a certain well defined level of performance over time, and if required to enhance the same through linkages with other systems without damaging the ecological integrity of the system'. According to Chopra (1993) in the next phase of the development of the Indian agriculture two types of aspects have to be considered: one, only increasing agricultural productivity may not necessarily sustain agricultural productivity in the long run and conservation has to be ensured and raise productivity to a limited extent. It shall, however, have to be kept in mind that when the primary goal is one or the other, negative repercussions for the other are kept within limits. Since irrigation is a part of increasing agricultural productivity, sustainability of irrigation system is also important to understand sustainability in agriculture. In principle, the irrigation or the irrigation system can make a contribution to sustainable agricultural development only if they do not lead to permanent degradation to the soil and water resources or of the social system; so that when an irrigation scheme is abandoned, another form of land use can take place without any difficulty (Wolff 1995). According to Abernethy (undated) the sustainability of irrigation system is threatened when the system no longer offers any economic advantage, it operates extremely well internally but has a disadvantageous effect on other interests, when people involved are no longer willing to bother about major aspects of the system and when in general the system comes under severe pressure.

These crucial aspects have been somewhat neglected in the recent literature, particularly in context of Punjab. It thus becomes relevant to compare the different irrigation systems that are canal, mixed and tube-well irrigation systems in terms of both trends in yield and its stability for wheat and paddy to arrive at a holistic appraisal of sustainability aspects of crop specialization in Punjab.

2 Framework of analysis

The major environmental problem arising out of intensive agricultural practices in Punjab is groundwater depletion, which is mainly a repercussion of overdraft of water through wells. The other problems arising out of intensive irrigation are water logging and salinity which is a salient feature of canal irrigated areas. But in the state of Punjab this is relatively less extensive in nature compared to groundwater depletion and is restricted to certain pockets. For example, the district that is most prone to water-logging is Kapurthala where the extent of affected area is only 3.73% while the highest share of geographical area covered by saline and alkaline land is found in Firozpur and Sangrur which covers less than one percent of their respective areas (NRSA 2001). In contrast, around 86% of the total area of the state is experiencing a problem of groundwater depletion (GOI 2000). It is evident therefore that in Punjab, the major sustainability problem is related to overdraft of groundwater through tube-well irrigation. In general, it is expected that tube-well irrigated systems will enjoy an assured and stable quality of water supply, leading to both higher levels and more stable yield (Kaul and Sekhon 1991). Canal irrigated areas, on the other hand particularly in semi-arid regions like Punjab, are normally associated with

Table 1 Structure of net area irrigated in Punjab

District-wise percentage of net irrigated area in Punjab by sources (1980–2000)

Districts	Canals			Wells		
	1980	1990	2000	1980	1990	2000
Gurdaspur	33.53	50.49	10.55	62.36	60.99	89.45
Amritsar	58.98	53.81	50.03	40.81	49.23	49.6
Kapurthala	2.95	0.92	4.95	97.05	99.17	95.05
Jalandhar	9.97	14.35	7.06	90.03	82.48	92.94
Hoshiarpur	14.08	13.98	11.99	85.63	90.24	86.77
Rupnagar	6.12	19.82	7.67	92.42	84.79	92.33
Ludhiana	8.32	4.79	2.63	91.68	95.62	97.37
Ferozpur	49.22	56.05	36.69	50.55	51.2	63.31
Faridkot[a]	75.83	74.53	29.29	24.17	29.18	24.11
Bhatinda	86.41	95.34	62.01	13.59	18.13	37.58
Sangrur	32.66	35.41	23.23	67.34	68.05	76.77
Patiala	11.72	9.98	2.54	87.84	91.08	97.38
Punjab	42.28	42.7	23.82	57.33	57.12	76.13

[a] The drastic shift from canal to tube-well irrigation in the district has taken place in the late nineties. The district has been chosen to represent a canal irrigated system which is characterised by a wheat–paddy cropping pattern

Source: Computed from various volumes of Statistical Abstracts of Punjab

Table 2 Selection of sample districts

Districts	Basis for selection
Faridkot	Dominantly canal irrigation system (approximately 75% irrigated by canal till late nineties). Only district that is characterised by a wheat–paddy cropping pattern with a dependence on canal irrigation
Kapurthala	Tube-well irrigation system (above 95% under tube-well irrigation from early eighties)
Amritsar	Mixed irrigation system (tube-well and canal irrigation comparable in extent over the years)

Note: The districts not having rice as a major crop in its cropping pattern have not been considered for selection of sample

fluctuations in yield due to uncertain water supply, which is particularly acute in the tail-reach of the canal-irrigated areas.

However, our contention is that, in this state, tube-well irrigated systems have been exploited beyond the sustainable limit and thus are expected to experience an increase in yield uncertainties. The percentage under groundwater irrigation in Punjab has been steadily increasing over a period of time in majority of the districts (Table 1). In districts like Gurdaspur and Kapurthala, the agricultural sector shifted its dependence in a significant way from surface to ground water sources in the late nineties. On the other hand, in six other districts, tube-well irrigation made up for more than 80% of the net irrigated area from as early as late seventies. A few districts can be categorized as mixed irrigation regions (Amritsar, Ferozpur and Sangrur). To capture relative performance of wheat–paddy cropping cycles in different irrigation systems, three districts have been selected which represent different irrigation systems. Since the focus of this study is to evaluate the relative performance of the wheat–paddy combination, only districts that had wheat and paddy as the first two crops were considered for the selection of sample districts. Table 2 provides the basis for selection of sample districts.

3 Expansion of area under wheat and rice

In Punjab, unlike most other states of India, the extent of irrigation has a lesser role to play in determining the cropping pattern because most of the districts enjoy an irrigation extent higher than 90%. Rather, the source of irrigation is often important in explaining the percentage share of the wheat–paddy cropping pattern, which has become the dominant crop cycle in the state in recent years.

Table 3 reflects that the regional structure of cropping pattern has changed substantially in the periods of early eighties and nineties and this has, to a large extent been determined by the availability of easy access to ground water for irrigation. To elaborate, in the early eighties, the diversified districts spread across the southern and central parts of the state, whereas a decade later, a general shift towards crop-specialisation took place and consequently, a wheat–paddy belt emerged which extended from south-west to north-eastern part of the state (Fig. 1). By 2000, out of twelve districts, ten had wheat and paddy as the two most important crops and six were characterised by an exclusive wheat–paddy crop-combination.

Wheat has been the major crop in the state even prior to the green revolution period,[1] though after the change in technology, the area under wheat expanded significantly. Subsequently, acreage under this crop stagnated, which was observable by the early 1970s. In the

[1] In 1960–1961, area under wheat was 30% of the gross cropped area.

Table 3 Crop combinations across districts (Weaver's method)

Districts	1980	1990	2000
Gurdaspur	WR	WR	WRSu
Amritsar	WR	WR	WR
Kapurthala	WR	WR	WR
Jalandhar	WRM	WR	WR
Hoshiarpur	WMTR	WMR	WMRSu
Rupnagar	WMRSuGTGrMaBC	WRMSuMoCABRP	WRM
Ludhiana	WRMGrCSuBMoPG	WR	WR
Ferozpur	WRCGRBMBjMo	WRC	WRC
Faridkot	WCRGRBBjMMoSu	WCR	WRC
Bhatinda	WCG	WC	CR
Sangrur	WCRMGBjGrB	WR	WR
Patiala	WR	WR	WR

Source: Statistical Abstract of Punjab (1979, 1980, 1981, 1989, 1990, 1991, 1999, 2000, 2001)

Note: Wherever the crop combinations are more than ten the names of the first ten crops are mentioned W-Wheat, R-Rice, M-Maize, T-Tobacco, Su-Sugarcane, R-Rapeseed and Mustard, G-Gram, Gr-Groundnut, Ma-Mash (fodder), Be-Barley, C-Cotton, Mo-Moong (type of pulses), P-Potato, Bj-Bajra (coarse cereal), A-Arhar (type of pulses)

decade of nineties, however, a slight fall of the proportion of area under wheat is noticeable for the state as a whole. Out of our sample districts, Amritsar and Kapurthala follow the same trend as that of the state. Faridkot, on the other hand, has registered an appreciable increase (5% points) in the share of area under wheat over the last decade (Table 4).

Paddy, which was a minor crop even in the seventies, has been growing steadily in importance in the state. This has been explained primarily by the increased dependence of Punjab agriculture on ground water. A close examination of the percentage of area under rice at various points of time starting from 1970 reveal that out of the three selected districts, Amritsar and Kapurthala had a relatively high percentage of area under rice from 1970 onwards. In Faridkot, the expansion of area under rice has really taken place from late nineties. The only district in Punjab where the proportion of area under rice has reduced after 1990 is Kapurthala and this decline is quite significant (3% points) in relative terms. Over the decade of nineties, Kapurthala has diversified into crops like sugarcane, potato, mustard, sesamum and bajra, which taken together as a group is a less water-intensive combination compared to wheat–rice cycle. Even sugarcane, which is known to be a highly water-intensive annual crop, requires 160 cm of water under the agro-climatic conditions prevailing in the state, which is less compared to the combined water requirement of wheat and paddy, which adds up to 174 cm *(Vaidyanathan GOI 1997*).

The above analysis reiterates that there is a close correspondence between the relative importance of wheat–paddy cropping pattern and the source of irrigation. Both Amritsar and Kapurthala, which had substantial area under tube-well irrigation, experienced a relatively early surge in the acreage under rice. Faridkot registered an exceptional increase in the same crop in the late nineties, which related closely with the increase in share of area irrigated by tube-wells. Another notable observation that can be made at this stage is that due to high and continuous dependence on groundwater and consequent cultivation of rice from very early years, Kapurthala is showing initial signs of withdrawal from the wheat–paddy cropping pattern.

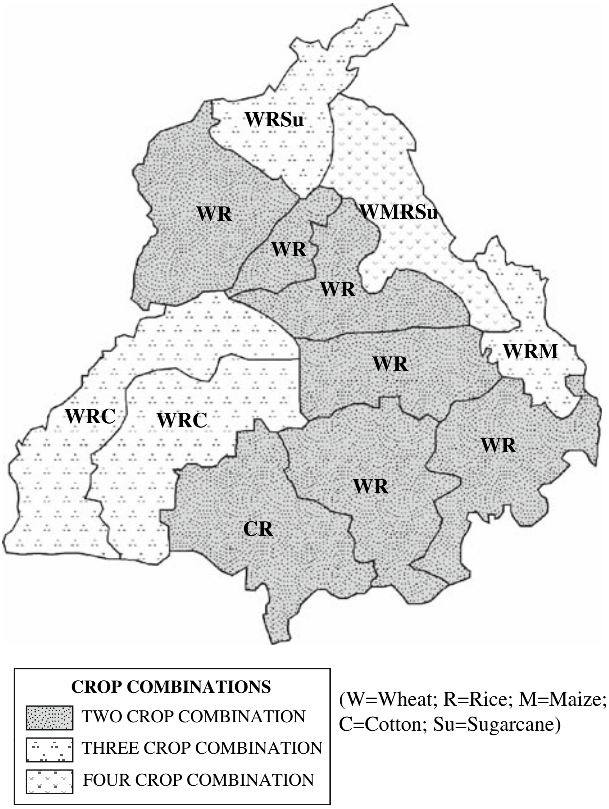


Fig. 1 Crop combination regions in Punjab 2000–2001. *Source:* Computed from Statistical Abstract of Punjab 2001

Table 4 Area under wheat and rice to gross cropped area (Figures in percentage)

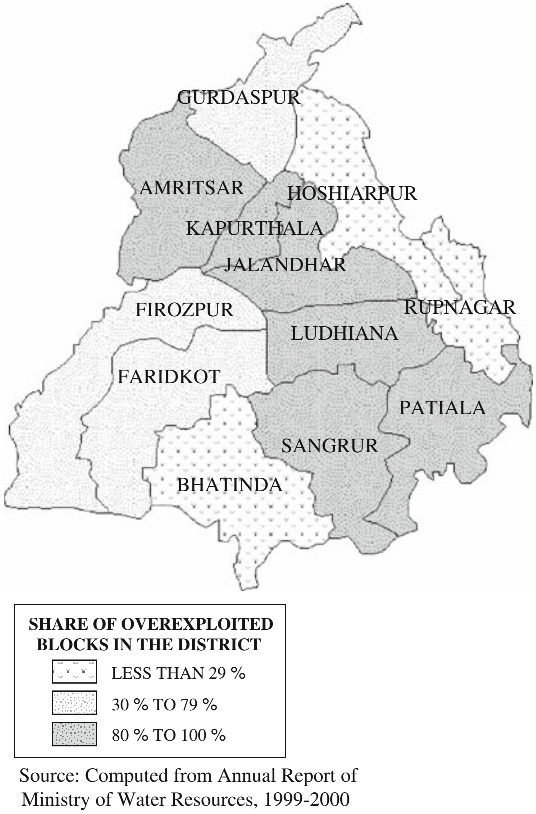
	1970	1980	1990	2000
Wheat				
Punjab	40.49	42.20	46.45	43.06
Amritsar	41.30	43.29	45.16	43.94
Faridkot	NA	41.78	43.22	48.45
Kapurthala	43.23	46.24	45.09	39.19
Rice				
Punjab	6.87	17.90	26.28	32.20
Amritsar	15.19	28.09	35.72	38.82
Faridkot	NA	10.18	11.53	30.12
Kapurthala	18.06	31.66	38.76	35.71

Source: Computed from various years of Statistical Abstract of Punjab

4 Consequences of wheat–paddy cropping cycle on groundwater situation in Punjab

It has been established that groundwater is primarily extracted for agricultural purposes, particularly for water intensive crops such as rice and wheat. Our spatial analysis of area under rice and wheat cultivation and groundwater depletion reiterates the same finding.

Fig. 2 Groundwater depletion in Punjab 2000. *Source:* Computed from Annual Report of Ministry of Water Resources 1999–2000



Figures 1 and 2 depict the comparative situation of crop combination regions[2] and groundwater exploitation at the district level, which clearly demonstrate a spatial correspondence of these two phenomena.

The districts with a wheat–rice combination are the ones which have been exploited beyond 85% of their respective groundwater potential. It may be observed that though Firozpur and Faridkot, which have a three-crop combination with rice as the second crop, do not show such high levels of exploitation of groundwater. This could be because the former is characterized by conjunctive irrigation at the district level (mixed irrigation systems), which is known to be more sustainable than either a dominantly tube-well or canal irrigation system. On the other hand, Faridkot shows a shift towards tube-well irrigation only after late nineties.

Table 5 highlights the problem of sustainability of groundwater resources in Punjab. In the 1990s, three out of twelve districts show a decline in the absolute area under tube-well irrigation. Among these three districts, Kapurthala and Ludhiana are the most intensively tube-well irrigated districts of the state for the last two decades (Table 1). The most probable reason due to which this may happen is a draft of groundwater over and above the recharge.[3]

[2] The method used to derive the crop combination regions is the Weaver's Method (Weaver 1954).

[3] It is also to be noted that Kapurthala is the traditional rice growing district of the state (Singh and Grover 1991).

Table 5 Trends of tube-well irrigation in Punjab (Compound growth rate in percentage)

Districts	1980–1990	1990–2000	1980–2000
Gurdaspur	2.67	3.00	2.83
Amritsar	2.49	0.48	1.48
Kapurthala	1.26	−0.99	0.13
Jalandhar	−2.78	5.71	1.38
Hoshiarpur	4.72	−0.11	2.27
Rupnagar	2.53	3.34	2.94
Ludhiana	1.32	−0.40	0.46
Firozpur	1.53	1.65	1.59
Faridkot	2.42	10.29	6.28
Bhatinda	4.50	8.36	6.42
Sangrur	1.14	1.02	1.08
Patiala	2.02	1.53	1.77

Source: Computed from various years of Statistical Abstract of Punjab

5 Trends in productivity of wheat and paddy

It can be expected that an unsustainable exploitation of any irrigation system would result in irregularities in yield trends of major crops. Tube-well irrigation in particular and ground water draft in general can be sustained over a longer period of time, if it is practiced in a conjunctive manner. More specifically, if there is a combination of surface and ground water manifested through canal and tube-well irrigation, the recharge from seepage of the canal system prevents depletion of ground water (Dhawan 1982). Given this background, our contention is that in the canal and the mixed irrigation systems, the yield levels would be sustained particularly for all crops in general and rice in particular compared with an exclusively tube-well irrigated system.[4] It is also expected that with time, the relative position of the latter system would worsen.

The observations regarding levels of productivity (Fig. 3) show that wheat productivity is consistently increasing in all the sample districts like the state as a whole. Similarly, in terms of rice (Fig. 4), an increase in productivity levels is definitely observed for the state as a whole, but the trends of increase among the different sample districts varies. The analysis of levels of rice productivity in over four decades reveal that Faridkot, which registered the highest yield levels among the sample districts in the first three decades consistently improved its relative position except in the last period. Also, the difference in the levels with Faridkot and Kapurthala increased continuously in the first three decades. This gap has been bridged up effectively in the triennium ending 2000 which can be explained by firstly, the drastic increase of area under rice in Faridkot and secondly, a downward adjustment in the wheat–paddy cycle in Kapurthala. Amritsar's consistent low levels of yield relative to that of the other sample districts cannot be explained at this stage.[5]

[4] It is expected that rice is being supported by tube-well irrigation even in Faridkot, where during the decades of eighties and nineties, canal was the main source of irrigation. This argument is strengthened by the fact that the increase of area under paddy in the district closely follows the trend of increase of well irrigation.

[5] A deeper investigation probably at the household level could explain the relative yield position of Amritsar. Factors as variety of seed, quality of irrigation, methods of cultivation are important in explaining yield levels.

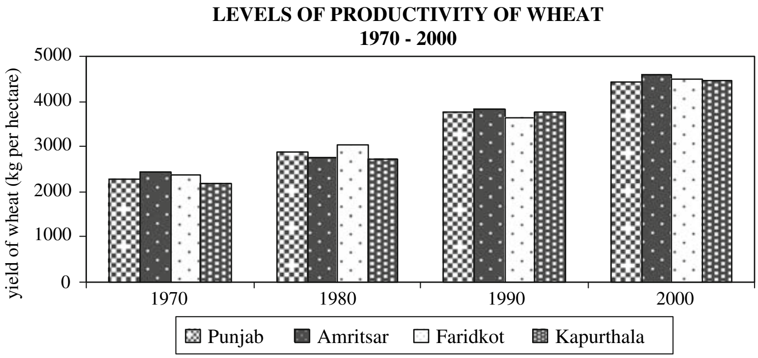


Fig. 3 Levels of productivity of wheat 1970–2000

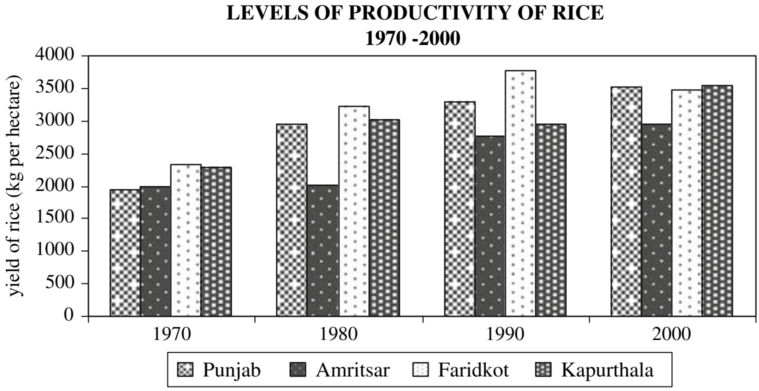


Fig. 4 Levels of productivity of rice 1970–2000. *Note:* Triennium averages have been considered

Table 6 Average annual growth rate in yields of wheat & rice (Figures in percentage)

Years	1970–1980	1980–1990	1990–2000
Average growth rate in yield of wheat			
Punjab	2.12	3.49	2.30
Amritsar	2.05	4.45	3.27
Faridkot	3.36	2.69	3.60
Kapurthala	2.07	3.49	3.84
Average growth rate in yield of rice			
Punjab	5.03	2.16	0.98
Amritsar	0.64	5.17	1.09
Faridkot	6.27	1.96	−0.89
Kapurthala	4.79	3.76	2.54

Source: Computed from various years of Statistical Abstract of Punjab

Note: The growth rates are computed by averaging growth figures of individual years

Stagnation in growth of yield of wheat has been observed from the nineties in the state and most of the sample districts (Table 6). This stagnation, however, is not applicable for our canal irrigated district, Faridkot, where the yield level has registered an increase in the last decade. The average growth rate of yield of rice has also declined, but consistently

Table 7 Sustainability of rice and wheat productivity: regression results

	Time	Dummy	R^2	Constant
Rice				
Amritsar	0.0006 (3.34)*	−0.0003 (−0.09)	0.552	3.31 (172.39)*
Faridkot	0.0004 (2.09)**	0.0009 (0.24)	0.368	3.445 (160.52)*
Kapurthala	0.00039 (5.36)*	−0.0093 (−2.93)*	0.538	3.363 (183.17)*
Punjab	0.0009 (6.48)*	−0.0053 (−1.87)***	0.744	3.334 (203.49)*
Wheat				
Amritsar	0.0008 (6.37)*	0.0056 (2.32)**	0.896	3.35 (235.82)*
Faridkot	0.0009 (9.41)*	0.0012 (0.64)	0.923	3.35 (307.46)*
Kapurthala	0.0009 (5.97)*	0.007 (2.47)**	0.890	3.308 (200.07)*
Punjab	0.0009 (10.39)*	0.0025 (1.49)	0.943	3.35 (342.55)*

*, ** Significant at 1 and 5% levels respectively

over the decades in all the sample districts following the pattern of the state as a whole. Amritsar, however, is the only district which has shown an increase in the eighties and thereafter has declined in the later decade. The high increase in the eighties in this district corresponds with its shift from canal to tube-well irrigation. It may be noted here that in Kapurthala, which had experienced a decline in the acreage of the wheat–paddy cropping system, the decline in growth rate of rice yield is gradual and less sharp compared to rest of the state.

Studies have shown that the exemplary progress after the introduction of high yielding varieties of wheat during sixties and rice during seventies have started showing stagnation in the late eighties (Kaur and Sekhon 2005). To have a further insight to this, a regression analysis is done taking 1987 as a benchmark. Taking time as an independent variable and productivity as the dependant variable a regression analysis is done to see whether saturation and stagnation has taken place in all the sample districts under study (Table 7).

It is seen that time explains productivity significantly as it is inevitable that productivity will change with time. But when the "before-after" approach is followed, the results vary. Faridkot is the only sample district which shows stagnation in productivity of wheat following the same trend as the state. The other two districts Amritsar and Kapurthala have rather experienced comparatively higher yields in the later period, i.e. after1987. In case of rice the results are drastically opposite. On one hand the districts of Kapurthala and Amritsar along with state is showing decline in yield in the later period, on the other Faridkot is indicating a saturation of productivity in the same. It should be noted that the downward adjustment of rice acreage in Kapurthala is a comparatively recent phenomena, but otherwise the long term sustainability of rice productivity in the district is a point under consideration. The underlying fact is that wheat, the traditional crop in the state is agro-climatically suited for the region and hence its productivity can still be sustained in the long run. But rice being a crop of the wet zone requires more water especially in arid and semi-arid conditions. In such a situation cultivation of rice creates pressure on the natural resource particularly groundwater resources making the whole agricultural system unsustainable.

6 Stability in productivity of paddy and wheat

Stability of yield is an important component of the larger sustainability concept. It has been established that the agricultural growth in Punjab has got plateaued in the late 1980s (Kaur

Table 8 Index of instability[b]

		Punjab	Amritsar	Faridkot	Kapurthala
Wheat	1970–1986	5.51	10.16	6.38	9.81
	1987–2003	4.84	5.81	6.09	7.18
Rice	1970–1986	6.05	12.32	15.12	6.58
	1987–2003	5.17	7.30	6.93	11.30
Maize	1970–1986	10.19	23.13	20.34	15.24
	1987–2003	12.88	15.55	NA	15.23

[b] Cuddy-Della-Valle index ($I = CV * (1 - R^2)^{0.5}$) has been used to measure instability where CV is coefficient of variation across the temporal data and R is Coefficient of Determination for the linear regression with productivity as the dependent and time as the independent variable. We believe that the use of coefficient of variation (CV) as a measure to show instability in any time series data has some limitations. If the time series data exhibit any trend, the variation measured by CV can be overestimated, i.e. a region whose yields are growing at a constant rate will score high in the instability scale. Thus, CV would not be an adequate method to capture stability/instability of yield. As against that the Cuddy-Della-Valle Index attempts to de-trend CV by using adjusted coefficient of determination or multiple determination (R^2 or $\overline{R}^2$). Thus, it is a better measure to capture instability in agricultural yield

Source: Computed from various years of Statistical Abstract of Punjab

and Sekhon 2005). Therefore, to analyze the agricultural stability in the state, a temporal analysis of instability in productivity has been attempted here and the variations in instability have been analyzed for two periods (1970–1986 and 1987–2003). It can be seen that wheat has shown an increased stability for all the sample districts and the state as a whole, as already corroborated in Section V. The scenario in terms of rice is not very different, except in the case of Kapurthala, where unexpectedly instability in the later period has had a noticeable increase. It should be noted that shift to tube-well irrigation was resorted in order to gain increase in sustained productivity as, one of the basic pre-requisites of HYV seeds was assured and timely irrigation (Sidhu et al. 1999). That even after having a tube-well dominated irrigation system for long, the instability has shown an increasing trend validates our premise that such an irrigation system is not sustainable due to depleting groundwater levels beyond replenishable limits (Table 8).

7 Conclusion

The purpose of our paper was to strengthen the existing empirical base of sustainability status of the wheat–paddy cropping cycle in Punjab. The treatment of empirical analysis of the paper was somewhat different from the existing studies as irrigation systems at various stages of development (represented by districts) were compared to evaluate comparative sustainability status. Three aspects of sustainability of the wheat–paddy cropping system has been touched upon—levels and growth of productivity, stability of productivity and water use efficiency in terms of irrigation.

The underlying hypothesis of this paper was that over-exploited ground-water dependent agriculture would tend to show signs of stagnation and instability unless they adjust their water intensive cropping pattern. To a large extent this view has been validated through our analysis, where it has been observed that out of the two selected over-exploited tube-well systems, the one which has been diversifying (i.e. Kapurthala), had significantly better performance in terms of most of the criteria used in this study compared with the one increasingly specializing in favour of the wheat–paddy cycle (i.e. Ludhiana). Also, the more recent tube-well irrigation system (Amritsar), has witnessed increases in yield levels as is characterised by lower levels of instability. Probably not surprisingly, the canal irrigated system is better off or comparable to the specializing and over-exploited groundwater system. In sum, diversifying agricultural systems in Punjab have a potential to not only improve in terms of their overall sustainability status, but also could have a positive externality impact on the residual wheat–paddy cropped area.

Our earlier analysis brings out an overall decline of the area under tube-well irrigation in Kapurthala.[6] These two aspects together reveal an unusual trend in this district with respect to the rest of the state. In the second case, depletion of groundwater has not necessarily led to a downward adjustment by the farmers in their land allocation towards rice–wheat cropping system.

1. Instability of rice yield has increased over a period of time.
2. Levels of productivity of both rice and wheat have also stagnated over a period of time.

These two points are amply illustrated given over our analysis. The above two problems are observed more clearly in the district dominated by tube well irrigation for a substantially long period of time compared to those where this analysis has emerged in the more recent years.

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[6] All the blocks in Kapurthala have been over-exploited i.e. more than 100% of its potential.

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