FOOD SECURITY AND SUSTAINABILITY: A COMPARATIVE STUDY OF PUNJAB AND UTTAR PRADESH

Dissertation

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(Minor Subject: Statistics)

By

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CERTIFICATE I

This is to certify that the thesis/dissertation entitled, **"Food Security and Sustainability: A comparative study of Punjab and Uttar Pradesh"** submitted for the degree of Ph.D. in the subject of **Agricultural Economics** (Minor subject: **Statistics**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Priyanka Singh (L-2016-BS-64-D)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that the dissertation entitled, **"Food Security and Sustainability: A comparative study of Punjab and Uttar Pradesh"** submitted by **Priyanka Singh (L-2016-BS-64-D)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of Ph.D, in the subject of **Agricultural Economics** (Minor subject: **Statistics**) has been approved by the Student's Advisory Committee along with External Examiner after an oral examination on the same.

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ABSTRACT

Ensuring food security has been the central theme of agricultural development policy. Therefore, studies are being increasingly taken up to assess the food security status from national perspective in recent past. Since, precise assessment of regional food security and its sustainability is prerequisite for strategic planning and prioritizing allocation of resources; the present study ascertained the sustainability of food security in the most populous and productive states of India i.e. Punjab and Uttar Pradesh. The study, using secondary data, examined the growth performance of foodgrains over a comprehensive period of TE1990/91-TE2016/17 and for the three decadal periods viz., TE1990/91-TE2000/01, TE2000/01-TE2010/11 and TE2010/11-TE2016/17 at national level and for the selected states. The production of food grains shows an impressive and significant growth (CAGR 1.60%) at national level during the whole period as well as in the sub periods with the highest growth in TE2010/11-2016/17 (CAGR 1.70%). Unlike in Uttar Pradesh, where foodgrains witnessed productivity led growth during the overall period; both increase in area and yield contributed in production growth of foodgrains in Punjab. The district wise composite index of sustainable food security for the selected states has been constructed from its components – food availability, access and utilization. Principal Component Analysis (PCA) technique was used to assign weights to indicators of each dimension of food security. In Punjab, the sustainability of food security increased as one moves from southern to northern parts of the state. Districts in the western (Fazilka, Muktsar etc.) and southern (Mansa and Sangrur) part of Malwa region of the state were rated low in sustainable food security index. In Uttar Pradesh, large number of district fell into the moderate range of sustainable food security index. The results of the study will support the decision makers in implementing suitable policy measures to address regional food insecurity in both the states.

Keywords: Food security, sustainability, Punjab, Uttar Pradesh

Signature of Major Advisor **Signature of the Student**

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Priyanka Singh

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

CHAPTER I

INTRODUCTION

1.1 Food security: Concept and Issues

Food security has become a likely predicament for the whole world in the 21st century. The concept has evolved, developed, multiplied and diversified, since the World Food Conference 1974 at Rome (Maxwell 1996). It is quite difficult to define it precisely, hence, till now around 200 definitions and 450 indicators of food security are accessible in different literatures but the nucleus of each one is more or less the same (IFPRI 1999, Maxwell and Smith 1992). Among all these definitions, the most welcomed one is "food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (CFS 2012 as per the FAO 2009 definition). Thus from this definition the four pillars of food security at number of levels: availability - national, access - individual, utilization - household and stability (FAO 2009) have been noticeably delineated and can be described under following sub headings:

- **Availability** – It connotes regular and sufficient availability of food at regional and national level through domestic production, imports, food assistance and food stocks.
- **Access** – This determines how efficiently individuals are able to utilize their resources in order to purchase and procure food.
- **Utilization** – This deals with effective absorption of food through safe drinking water, sanitation and healthcare facilities for attainment of nutritional well-being in order to meet all the physiological needs of a healthy life.
- **Stability** – This represents potential of a nation / community / household to resist any kind of natural or manmade shock to the food system.

The idea of food security has developed gradually overtime and the belief of sustainable development has been highlighted in the recent developments, thus sustainability has been introduced as the fifth dimension by international organizations (Berry *et al* 2015, Richardson 2010). As sustainability mainly encompasses four interrelated domains: ecology, economics, politics and culture, therefore it is pre condition for long term food security of future generations (Berry *et al* 2015).

Over the past decade, there has been improvement in the global food security scenario still it is not free from challenges and issues (Tandon *et al* 2017) which is undoubtedly indicated by the growing quantum of hunger and food insecurity. The number of people suffering from chronic hunger has shot up from 804 million in 2016 to 821 million in 2017 in the world (FAO 2018). The severity of the issue for the entire world is clearly reflected from

the commitments of United States to ensure global food security by 2030 (FAO 2016a) through placing ‘‘end hunger, achieve food security & improved nutrition and promote sustainable agriculture’’ as one of the core objective of Sustainable Development Goal (SDG).

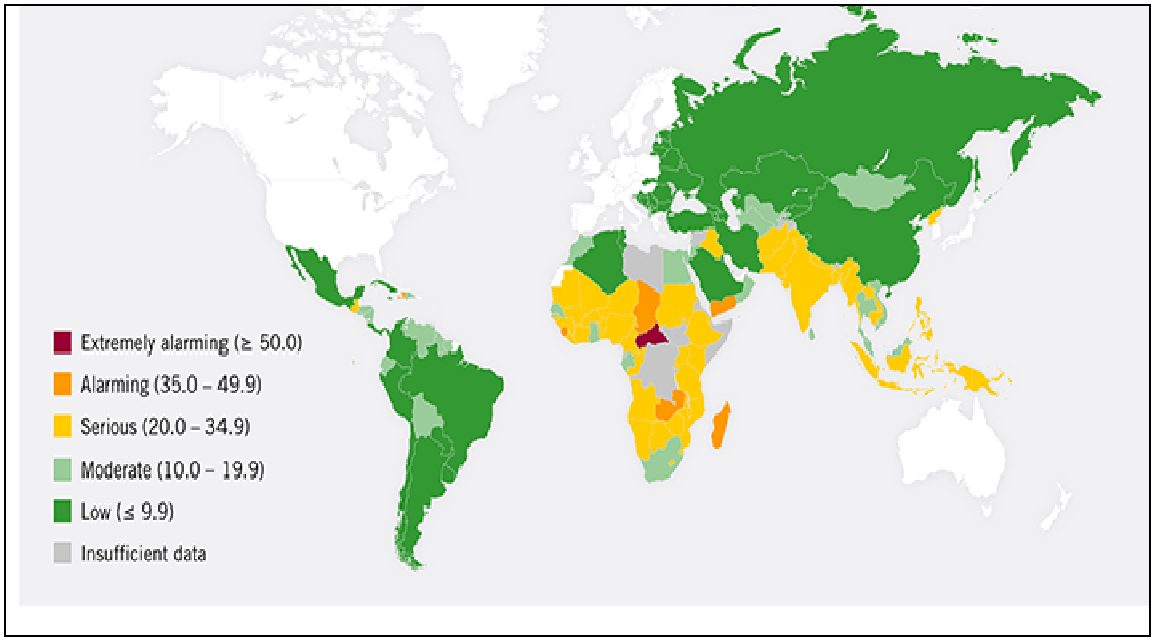
There are number of factors which threaten food security, the biggest challenge is to feed the growing population which is expected to reach approximately 9.2 billion by 2050 (Tandon *et al* 2017). The increasing risks from climate change along with increasing pressure on natural resources, land degradation and depletion due to unsustainable practices and competition for ecosystem further exacerbate the looming threat of food insecurity across the globe. In the recent years, climate variability is the key driver for acute food crisis and is negatively affecting all the four pillars of food security (FAO 2018).

Worldwide, the South Asian region is highly sensitive to the consequences of climate change (Mittal and Sethi 2009). Accordingly, the high climate sensitivity of the region in addition to poor infrastructure, low level of regional integration, inappropriate policy framework has critically obstructed the region from ensuring food security. Even, several literatures indicated that climate change will cause yield declines for the most important crops to a lager extent and South Asia will be particularly hard hit (IFPRI 2009). Therefore food security issues have captured special attention in south Asian regions despite of its high economic growth in the recent past (Mittal and Sethi 2009, Timmer 2013).

1.2 India’s Food Security: Status and Challenges

Food security has been the central theme of agricultural development policy in India ever since mid-1960s. Since the Green Revolution in the late sixties, the agricultural policies have been oriented towards a rapid increase in food, particularly rice and wheat production, to meet the basic nutritional needs of a growing population. The glorious journey of the nation in achieving self sufficiency in terms of food production and minimizing the fluctuations is well documented, however a large chunk of population in the country have been reported to face chronic food insecurity (Radhakrishna and Reddy 2004). Nevertheless, the country has witnessed impressive economic growth in the recent years, all its accomplishments plummet down when one look into the widespread poverty and hunger situation. India is home to 14.5 per cent of hungry and malnourished population (FAO 2019) and in the recently released Global Hunger Index (GHI) report, 2018, the country has been ranked at 103 out of 119 qualifying nations and falls under *serious* category reflecting the severity of food insecurity in India (Grebmer *et al* 2018). India also has the unenviable problem of ensuring food security for the projected most populous country in 2050 with one of the largest malnourished population (Sehgal *et al* 2013). Further, the changing climatic regimes are expected to pose additional stress on India’s long-term food security challenges (FAO 2008, Campbell *et al* 2016).

Figure 1: Global Hunger Index (GHI), 2018



Source: Grember *et al* 2018.

The studies of national interest have reported the untapped potential of agricultural sector that need to be exploited in an environmentally sustainable manner in order to reduce poverty, hunger and improve the food security scenario of the country (Nadav 1996, Irz *et al* 2001, Majid 2004). However the crux of India's food problem does not lie much with the availability of food, but its distribution (Jain 2016) as growth can ensure increased availability of food but not the accessibility and utilization of the same.

Government of India, in order to address the serious and complex issues of food insecurity, has taken several initiatives in the recent past both at national and regional level. The enactment of National Food Security Act, 2013 that legally entitles upto 75 per cent of the rural population and 50 % of the urban population to receive subsidized food grains under Targeted Public Distribution System is one of the sincere efforts in this direction. The enforcement of Chhattisgarh Food Security Act, 2012 by the state government of Chhattisgarh; and "Amma Unavagam (Mother's Canteen)" scheme launched by government of Tamil Nadu in 2012 are important policy initiatives at regional level to be cited. However, the effectiveness and efficiency of the aforesaid programmes are further researchable issues.

Statement of the Research Problem

Research studies conducted at global and national level largely remained biased toward interlinking the food security with crop production system (Nandakumar *et al* 2010, Narayanan 2015), and has overlooked the vital role of livestock sector in ensuring food security of rural masses. The significance of livestock sector in agricultural economy like India doesn't need much emphasis. The sector being generator of cash flow and economic buffer for weaker section of society is crucial in overcoming the formidable challenges of

food access for them.

The review of literature which follows in the next chapter indicates that in a large number of studies, current availability of food has been accorded prime place for ensuring food security. The sustainability of food availability and access which is crucial for ensuring the food security of future generation has been largely ignored. Even some literature suggests that without integrating sustainability as an explicit dimension of food security, today's policies and programmes could become the very cause of increased food insecurity in the future (Berry *et al* 2015). To feed the growing population, food is being produced at the cost of critical natural resources as evidenced by degradation of soil, lowering of water tables, clearing of forests (Pimentel *et al* 1997, Richardson 2010) and thus it poses a threat for the security of future. Therefore, a comprehensive study to assess the status of food security with due consideration of sustainability dimension would be an urgent policy imperative.

Nevertheless, various research studies around the globe are being increasingly taken up to assess the food security from national perspective, in depth studies at the regional level is scant. Precise assessment of food security and its sustainability status at regional level is prerequisite for strategic planning and prioritizing allocation of resources for ensuring food security for the future generations.

The choice of the study area has been guided by the fact that the state of Punjab and Uttar Pradesh has been heralded for its contribution to the food security of the nation. These states have an added advantage of their geographical location in the most fertile Indo-Gangetic plains which is the heart belt of green revolution (Sekar and Pal 2012) and is blessed with excellent land and water resources as well as favorable climatic conditions best suited for agriculture. Together they comprise around 15 per cent of total geographical area of the country and contribute around 28 per cent of the total food grain to the central pool. However, the emerging scene of agriculture in both the states has become a matter of serious concern. The productivity of paddy and wheat, which is the top priority for the country as staple food, has almost reached a plateau in Punjab (Grover *et al* 2016). The state cropping pattern dominated by wheat-rice rotation is causing a serious damage to the state's natural resource base. On the other hand, the crisis of agriculture in Uttar Pradesh is in a nascent stage reflected by stagnating total agricultural output, growing incidence of indebtedness of farmers and insufficient returns to cultivation (Raman and Khan 2017).

Against this backdrop, the present study **"Food Security and Sustainability: A Comparative Study of Punjab and Uttar Pradesh"** has been undertaken in the most populous and productive agricultural production system of the country i.e. Punjab and Uttar Pradesh with the following objectives:

1) To examine the trends in the pattern of food grain production and distribution overtime in India.

2) To analyze the trends and contribution of selected states in food grain production in India.
3) To study the developments in sustainability of food security in selected states.
4) To draw policy implications for sustainable food security in India as well as the selected states.

CHAPTER II

REVIEW OF LITERATURE

A comprehensive review of literature is a basic component of any research endeavor. It aids in delineation of the problem area and provides a basis for interpretation of empirical perspective of research. For conducting any empirical investigation, the review of research work already accomplished in the field in which the researcher intends to conduct a study is needed. It has utmost importance in formulation of hypothesis, proper research design, conducting research and also for relating past findings with current study. Also critical appraisal of the earlier studies makes it possible to assess the knowledge gap, lacunae in those studies and work out on possible improvement upon them. Thus review of literature regarding a particular research problem helps the researcher immensely to set out objectives of researcher problem and to follow the possible methodology to achieve the objectives.

Therefore, research works which relates to the objectives of the present study are reviewed under the following headings:

2.1 Growth performance and distribution of food grains at national level.

2.2 Growth performance of food grains at regional level.

2.3 Sustainability of food security.

At the end, gaps in available literature are summarized.

2.1 Growth performance and distribution of food grains at national level

In the early sixties, the expansion of area as major factor to the growth in production of food grains has been well documented in the literature (Abrol 2000, Bhalla and Singh 2001, Vaidyanathan 2010). However with the advent of green revolution, the technological breakthrough in rice and wheat that significantly augmented the productivity of the crops considerably reduces the pressure on area expansion of food grains to meet the national food demand. While analyzing the trend in food grain production, Kannan (2012) reported that over a period from 1967-68 to 2007-08, the food grains production registered an annual growth rate of 2.27 per cent and it was primarily attributed to growth in yield (2.33 per cent per annum) since area under total food grains experienced a negative growth rate (0.07 per cent per annum) over the same time period. Some other studies at national level, Desai and Shah (1978), Haffis *et al* (1992), Bhalla and Singh (1997), Goel and Sunaina (2012) reported the productivity led growth in food grain production in post green revolution period.

The instability in agricultural production in India over the time due to its reliance on monsoon and other climatic constraints does not need much emphasis. Therefore, renewed inquiry on decadal growth pattern of food grains perceived to be more policy imperative, especially in formulating food security strategies for the country. In this backdrop, Narayanmoorthy and Alli (2012) in their study covering the period of 1950-51 to 2010-11,

reported gloomy trends in area under food grains over the successive decades, and the production and productivity growth also portrayed a dismal picture during same period. They observed continuously and significant decline in the area under food grains till nineties, however, in 2000s area increased marginally. Again the production and productivity depicted the same trend with average increment being lowest during 2000s. Further, both the production and productivity of food grains decelerated substantially in comparison to previous decades considered for the analysis. Similar pattern of persistent decline in area under food grains and slumping of its production and productivity growth has been reported in other contemporary studies (Dasgupta and Sirohi 2010, Government of India 2011, Kannan and Sundaram 2011, Sharma 2012).

Paddy, wheat, nutri cereals and pulses are the major contributors of food grain basket of the country. Kannan and Sundaram (2011) observed an annual growth of 2.06 per cent in production of total cereals from a period of 1967-68 to 2007-08. This increased production of total cereals was principally the productivity led growth (2.12 % per annum) since the area under the total cereals declined (0.06 % per annum) during the given time period. However decadal trends indicated comparatively higher growth in production as well as yield, while the area under cereals registered negative growth in the post green revolution period i.e., during 1980-81 to 1989-90. As the growth rates among different crops were not consistent, hence studies (Mander and Sharma 1995, Sharma and Joshi 1995, Joshi *et al* 2005) have been conducted to look into the annual growth in area, production and productivity of each crop individually.

Kannan (2012) reported that the production of paddy and wheat registered splendid annual growth rate of 2.47 and 3.63 per cent, respectively, from a period of 1967-68 to 2007-08. As area under the crops, viz., paddy and wheat, has been reported to increase with marginal rate of 0.45 and 1.14 per cent, respectively; production growth was mainly attributed to increase in productivity of the two national staple crops. Over the same time period, the production of coarse cereals increased with a marginal rate of 0.56 per cent per annum which solely attributed to growth in yield (1.93 % per annum) as the area under the coarse cereals declined significantly (1.35 % per annum) over the period.

In another study, Goyal and Singh (2002) examined decadal trends in cereal crops during 1960 to 1999. The growth in production of rice crop showed continuously increasing trend till 1980s; however, the production growth declined during 1990s mainly due to decline in the yield growth. Contrarily, in wheat, the production growth was lower during 1970s, 1980s and 1990s over their previous decades due to drastic fall in yield growth during 1970s and decline in growth of area during 1980s over the previous decade. However, in 1990s the decrease in yield growth was compensated by significant growth in area under wheat crop. In coarse cereals continuously declining growth in area has been reported except in 1960s,

however, positive yield growth compensated the fall in area and kept the production growth rate positive.

In a recent study on India's agricultural development, Sharma (2012) reported negative growth (-0.70 per cent per annum) of area under rice during 2000s. The production growth of the crop has also declined during the same decade to 1.67 per cent per annum from 1.87 per cent per annum in previous decade (1990s). However, growth in productivity of the crop improved during 2000s over the previous decade. In wheat crop, area, production as well as yield growth rate continue to decline even in 2000s. In case of coarse cereals, there was improvement in the growth rate of production relative to the preceding decade and was totally productivity led growth as area under coarse cereals continually declined at higher rate from 1980s to 2000s.

Devi *et al* (2017) analyzed the trends in pulses production in India over time period 1950-51 to 2014-15. They reported that increase in pulses production during the considered period was the outcome of increase in productivity as the increment in area was not significant. They divided the entire period into three phases and noticed that during the pre-green revolution period (1950-51 to 1964-65) there has been significant increase in the production of pulses due to area led growth while in post green revolution period (1966-67 to 1994-95) production growth was mainly attributed to increase in productivity of pulses. However in the post economic liberalization period (1996-97 to 2014-15), negative growth rate has been reported in pulses production despite of positive and significant growth rate of area and yield.

In another national level study on pulses, Rimal *et al* (2015) reported the decadal growth rate in pulses production over a period of 1982-2012. In 1980s, area under total pulses registered negative growth of 0.25 per cent per annum. Therefore, production of pulses which grew at compound annual rate of 0.66 per cent was mainly due to growth in yield which registered the annual growth rate of 0.91 per cent during the same period. Thereafter, in 1990s, annual growth in production decreased significantly to the extent of 1.06 per cent due to the negative annual growth in area (0.69 per cent) as well as in productivity (0.38 per cent). However, magnificent growth has been observed in the production (3.93 per cent per annum) of pulses in 2000s basically due to improvement in their yields which reported to grew annually by 2.69 per cent. During the same period, area under pulses also witnessed compound annual growth of 1.21 per cent. The productivity led growth in pulses was also reported by Dasgupata and Sirohi (2010), Sharma *et al* (2013) and Devegowda (2018) in their studies on production growth of pulses, however period considered by them for analyzing trend were different.

Besides growth in production of food grains over time, its distribution is equally imperative in ensuring food security. It's therefore become important to analyze trend in

distributions of food grains. A good number of studies, however in different perspective, have been carried out on procurement and off take of food grains at national level over various time periods. Khera (2011) in her study on diversion of food grains reported a sharp increase in procurement of wheat from around 147 lakh tones in 2004-05 to around 253 lakh tones in 2008-09. During the same period, the procurement of rice increased by around 90 lakh tones from 246 lakh tones in 2004-05. Further, they observed increase in per capita purchase of PDS rice and wheat in rural India from 2001-02 to 2007-08; however the increment in purchase was more in case of rice. Her study expressed serious concern on leakages from the public distribution system (PDS) that increased from 24 per cent in 1999-2000 to 54 per cent in 2004-05. Diversion of food grains was also critically addressed by Jha and Ramaswami (2010), Himanshu and Sen (2011) in their studies.

Balani (2013) in her study on functioning of Public Distribution System (PDS) accentuated the increased proportion of off take of food grains to allotment from 2003-04 to 2011-12; however the upsurge was mainly due to downturn in allotment form around 71 million tons to 40 million tons over the same period. The procurement of food grains also hiked to 70 million tons in 2012-13 from 38 million during 2003-04. In a similar kind of study, Basu (2010) also examined procurement of rice, wheat and coarse cereals and reported fluctuation in procurement of wheat and coarse grains from 2004-05 to 2009-10, while in case of rice it has continuously increased over the same period.

Kumar *et al* (2012) carried out in depth analysis on procurement of food grains both in absolute and relative terms from 1972-73 to 2010-11. They observed that procurement of rice has not only significantly increased in absolute amount but also showed sharp increase as proportion of their production from 6.4 per cent in 1972-13 to 34 per cent in 2010-11. The intensity in procurement of wheat also witnessed similar trend during the period under consideration. They further emphasized on wide fluctuation in intensity in the procurement of both the crops especially before 1999-2000.

2.2 Growth performance of food grains at regional level

In an attempt to measure regional food security status, numerous studies imputing growth rates of area, production and yield of important crops across the major states and geographical regions are available (Hazell 1982, Dev 1987, Chand and Sharma 1994, Bhagat 2000).

Bhalla and Singh (2010) have made a significant contribution in economic literature pertaining to regional growth pattern of agricultural output. In their comprehensive study, they estimated the growth rates of agricultural output in 17 major states of the country representing four broad regions viz., *North-Western region* encompassing Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab and Uttar Pradesh*; Eastern region* which covers states of Assam, Bihar, Orissa and West Bengal; *Central region* covering Gujarat, Madhya Pradesh,

Maharashtra and Rajasthan; and *Southern region* with Andhra Pradesh, Karnataka, Kerala and Tamil Nadu. Further the whole study period that was TE 1962-65 to TE 2003-06 was alienated into three periods with notable historical significance in Indian agricultural development namely, *green revolution period* (1962-65 to 1980-83), *pre-reform period* (1980-83 to 1990-93) and *post liberalization/reform period* (1990-93 to 2003-06). Over the entire period of 1962-65 to 2003-06, the growth in total agricultural which increased at an annual rate of 2.36 per cent was primarily yield-led growth. *North-western region* accorded highest growth rate (2.85 per cent) followed by *central* and *southern region* while lowest growth rate of 1.76 per cent was observed in the *eastern region*. In the *initial green revolution period* (1962-65 to 1980-83), with striking annual productivity growth of 2.53 per cent, all the states in *north-western region*, especially Punjab and Haryana, registered significant high growth rates in agricultural output. On the contrary, productivity growth rate in *eastern region* was less than unity (around 0.73 per cent) and thus output grew with least rate compared to the other region during the same period. The period 1980-83 to 1990-93 brought turning point in India's agriculture, as the growth in agricultural output shot up to 3.37 per cent from 2.24 per cent in the previous period. In *north-western region*, nonetheless, Punjab witnessed slow down in the growth rate in comparison to earlier period while Haryana and Uttar Pradesh recorded significant increase in the growth rate of output. All the states in *eastern region* also shown notable improvement in their productivity as well as output growth rate, except Assam where increase in the output was marginal during *pre reform period*. States of the *central region* presented a mixed picture while in *southern region,* especially in Tamil Nadu, significant acceleration in the growth rate was observed during the same period. The *post liberalization period* (1990-93 to 2003-06) was marked by sharp decline in productivity growth (CAGR 1.52 %) as well as output growth rate (CAGR 1.74 %) at the national level with maximum decline in southern region of the country (CAGR 0.48 %). This significant decline in the productivity and output growth rate in post liberalization period was mainly attributed to decrease in investment in agriculture as well as rural infrastructure. However, the state of Gujarat was seemed to be resilient from productivity shock and made significant contribution in central pool of the nation with remarkable annual yield growth of 4.55 per cent during the *post liberalization period.*

In addition to these regional specific studies, numerous studies at state level have been attempted to observe the growth rate in area, production and productivity of agricultural crops during different periods of time. In a recent study, Roy *et al* (2015) examined the growth performance of agriculture in the North-Eastern region covering Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Tripura for a comprehensive period of 1972-73 to 2011-12 and three decadal periods viz., 1982-83 to 1991-92 (decade I), 1992-93 to 2001-02 (decade II), 2002-03 to 2011-12 (decade III). The authors observed

positive growth in area, production and yield in the entire region for the overall period with Nagaland leading in all the three parameters followed by Arunachal Pradesh and Mizoram. The growth in food grain production during decade I and II was area led growth with 74.8 and 50.3 per cent estimated area effect during both the decades, respectively. Increase in productivity of crops was reported to be prime cause of growth of food grains during the third decade for the north-eastern states, with exception of Nagaland and Sikkim. In another contemporary study of the same region, Sharma (2013) reported similar trend in the area, production and productivity of food grains.

Acharya *et al* (2012) analyzed the growth rates of various food and non-food crops from 1982-83 to 2007-08 in Karnataka and reported that total cereals have registered significant acceleration in their production during the stated period. The output growth was exclusively productivity led growth since area under total cereals declined significantly during the same period. The cultivated area of rice and maize was reported to grow significantly during their study period. Further, the significant positive growth in pulse production in Karnataka during the two and half decade period was attributed to both area and yield growth. However, area expansion was reported to be significant factor in production growth of vegetables and spices in the state. They further observed positive, though non-significant, growth in production of oilseeds and commercial crops. Sserunjogi (2014) and Pavithra *et al* (2018) also examined growth pattern of important crops in Karnataka over different time periods.

In the state of Tamil Nadu, Saravanadurai and Kalaivani (2010) examined production growth of cereals from a period 1993-94 to 2007-08 and observed that during the period under consideration, among all cereals only maize registered positive and significant growth in production conditioned by considerable area expansion as well as productivity growth of the crop. The studies by Jahanmohan *et al* (2005) and Meenakshi and Gayathri (2006) are other important concurrent literature on examining growth pattern of important crops of the state; nevertheless, their considered periods are different.

The state of Andhra Pradesh, which falls in agro-climatic zone X and XI of planning commission is another agriculturally important state of the country due to its diverse climatic conditions suitable for wide range of crops. Therefore, production growth pattern of crops in the state has been important investigation area in studies pertaining to food security (Reddy 2011, Kumar *et al* 2018). In a detailed study Mouzam *et al* (2015) reported yield led growth of total food grains (includes both cereals and pulses) during the period of 1980-81 to 2009-10. They also observed that paddy, which is a prime cereal crop of the state, marked significant rise in yield-led production and area under the crop turned down during the study period, though the decline was not significant. The growth in production of pulses in the state was due to considerable rise in area under the crop as well as its productivity growth during

the same period. In case of oilseeds, nonetheless, area and yield witnessed significant rise in its growth rate, production registered positive but insignificant growth. Further, growth in production of tobacco was conditioned by productivity enhancement over the same period as its cultivated area declined significantly.

Similarly, trends in agricultural growth in state of Madhya Pradesh, where pulse and wheat are cultivated as major crop, has been studied by Gulati *et al* (2017) for the period 2000-01 to 2013-14. In their detailed analysis they reported that the contribution of food grains declined to 27.3 per cent in TE 2013-14 from 30.9 per cent in TE 2002-03 in the gross value of output from agriculture of the state. The decline was mainly attributed to decline in the share of jowar, barley, maize and small millets within the cereals group. On the contrary, wheat recorded gradual and significant increase in its production along with the area during the given period. Further, contribution of pulses, especially gram and tur, also declined in the gross value of output from agriculture; however, in terms of production, gram recorded positive growth from 1.9 million metric tonnes in TE 2002-03 to 3.4 million metric tonnes in TE 2014-15. The production of arhar marginally increased by 0.3 million metric tonnes over the same period.

Likewise many other studies on the growth performances of agricultural crops over various periods in different Indian states like Maharashtra (Mitra 1990), Odisha (Paltasingh and Goyari 2013, Pattanaik and Nayak 2014, Samal *et al* 2017) and West Bengal (Nandy and Siddhanta 2000, Ghosh 2010) were found during the review of literature.. As assessment of food security status in the state of Punjab and Uttar Pradesh is subject matter of the present investigation, studies accentuating growth pattern of food grains production in both the state have been keenly reviewed.

Punjab economy has achieved high growth trajectory with the adoption of new agricultural technologies. However, the state, predominantly a food grain economy, was not able to sustain this agricultural growth rate and it has declined gradually overtime (Singh *et al* 2012, Pandey 2014). Gulati *et al* (2017) in their study suggesting strategies for getting Punjab agriculture on high growth path, reported that during the period 1971-72 to 198-86, the agricultural sector in the state was growing at the annual rate of 5.7 per cent which was much higher than the national average (2.31 % per annum). However, the state witnessed a sharp drop in agricultural growth rate to 3 per cent during 1986-87 to 2004-05 which further squatted to 1.61 per cent in the recent decade i.e., 2005-06 to 2014-15. Among food crops, rice and wheat alone constitute 80 per cent of the total cropped area in the state. Further analysis revealed that the production of wheat increased from 4.8 million tonnes in TE 1970-71 to 16.4 million tonnes in TE 2014-15 while its share in the national food basket declined from 23.2 per cent to 17.9 per cent during the same period. Similarly during TE 1970-71 to TE 2014-15, production of rice increased from 0.57 million tonnes to 11.25 million tonnes as

well as its contribution also shot up from 1.40 per cent to 10.6 per cent.

In another study Grover and Singh (2012) examined the trends in area, production and yield of kharif and rabi pulses in Punjab for a comprehensive period of TE 1990-91 to TE 2007-08 as well as for the two sub periods viz., TE 1990-91 to 1997-98 (PI) and TE 1998-99 to 2007-08 (PII). They reported that the acreage as well production of major rabi pulses (masur and gram) declined significantly during overall period as well as in sub periods PI and PII; though in case of gram, the decline in area under the crop was insignificant in PII, and yield of the crop improved in the overall period and in the sub period PII. The acreage and production of kharif pulses (mash, arhar, moong) decreased significantly during the overall period of TE 1990-91 to TE 2007-08, however the productivity of mash crop improved significantly while that of arhar and moong recorded non significant decline during the same period.

Verma *et al* (2017) studied the sources of agriculture growth in Uttar Pradesh where wide variety of crops is produced, thus known as the 'granary of the nation." The researchers reported that the agriculture GSDP in the state during the period 2000-01 to 2014-15 grew at annual rate of 2.5 per cent and it was below the national average of around 3 per cent per annum for the same period. Also, In TE 2013-14, the area share of total food grains to gross cropped area declined by 2 percentage point from 80 per cent in TE 2002-03. In 2014-15, the state with a production of 25.2 million tonnes was the largest producer of wheat in the country, however, its contribution to central pool (29.9 %) was lower than that of TE 2002-03 (35.5%). Similarly, its share in central rice pool also tumbled down, though marginally, during the same period. They further reported that production of total cereals witnessed significant increase from 39.4 million tonnes in TE 2002-03 to 45 million tonnes in TE 2014-15, whereas during the same period production of pulses declined significantly from 2.25 million tonnes to 1.82 million tonnes. The state of Uttar Pradesh is also heralded as "sugar bowl of nation" and production of sugarcane shot up significantly from 115 million tonnes to 133.4 million tonnes during the study period, however, its share in gross cropped area remained almost stagnant since TE 2002-03.

A more or less similar picture of trend in area, production and productivity of food grains in Uttar Pradesh have been reported in others studies like Singh and Chandra (2001), Srivastava *et al* (2003), Bajpai and Volavka (2005), Goyal and Kumar (2013), Singh and Supriya (2017), though their study period under consideration varies.

In a study on growth performance of pulses in the major producing states of the country for 1980-81 to 2001-02 as well as for the two sub-periods i.e., 1980-81 to 1990-91 (pre reform) and 1990-91 to 2000-01 (post reform), Tuteja (2006) reported that Uttar Pradesh witnessed negative growth rate in pulse production during the whole period, however, in the pre reform period it was positive. The growth performance of arhar was dismal in the state as

area, production and yield registered negative growth rate in overall as well as sub periods expect in post reform period where yield improved marginally. Remarkable decline in the area under gram has been reported in the state in comparison to other states during the aforesaid study periods and accordingly production also turned down significantly. The productivity of gram shown positive growth rate but it could not compensate for area decline; therefore gloomy picture in pulse production trend has been observed.

2.3 Sustainability of food security

Despite of improvements in the theoretical understanding regarding food security, its measurement has remained a challenging task among scientific circle due to its multidimensional and complex nature (CFS 2011). The plethora of definitions and indicators of food security further accentuate its conceptual ambiguity (Hart 2009). However, the assessment of status of food insecurity of households or a region is necessary for optimal policy formulation and implication.

Substantial efforts have been made in the last couple of decade to assess food security of households at national level, among which, dietary energy intake method (FAO method), consumption and expenditure survey based approach, anthropometric measurements, food gap and psychological measures are few that gained attention in economic literature (Escamilla and Correa 2008). However, the choice of a particular method largely depends upon questions to be answered.

The regional assessment of food security requires comprehensive selection of indicators corresponding to each dimension (availability, access, utilization and stability) of food security that suits the area of the study. Use of area specific indicators in constructing a single composite index of food security is well documented (CFS 2011, Pinstrup Andersen 2009). In a more comprehensive study at global level, Napoli (2011) constructed Food Insecurity Multidimensional Index (FIMI) for cross country comparison of 61 nations using 20 indicators for the four dimensions of food security. Wineman (2014) in rural Zambia, Demeke *et al* (2011) in Ethiopia, Solaroli (2015) in Mediterranean countries, Browne *et al* (2015) in African countries, Adjimoti and Kwadzo (2018) in rural Benin followed the same indicator based approach in assessing the status of food security.

The World Food Program's Vulnerability Analysis and Mapping Unit apply principal component analysis (PCA) to develop a food security and vulnerability index for household profiling (WFP 2009). A number of studies have followed this PCA technique to construct a composite index of food security in order to assess how food secure is a region in terms of overall food availability, access as well as utilization.

In Indian context, Pandey (2015) also followed indicator based approach in assessing food security status of seventeen states and their ranking based on respective index value. He used seven broad indicators for the three dimensions of food security viz., affordability,

availability, and food absorption. Equal weights were assigned for each dimension and the overall sore for the food security index ranged from 0 to100. States of Kerala, Haryana, Punjab were in better position in terms of affordability than rest of the states while Bihar scored lowest rank for the same. States of Indo-Gangetic plains viz., Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal were comparatively better in food availability status while southern (Tamil Nadu, Andhra Pradesh, Karnataka) and western (Gujarat and Maharashtra) region of the country ranked higher in food absorption category. The composite food security indices value showed that Punjab, Haryana and southern states were more food secure, while in eastern region (Bihar, Jharkhand, Odisha) where poverty ratio is also very high, high percentage of population were less food secure.

In a regional level study Shakeel *et al* (2012) assessed the food security scenario in Bundelkhand region of Uttar Pradesh. They used 13 indicators pertaining to the three dimensions - availability, stability and accessibility, for constructing composite index for the seven districts of the region. Food security in Bundelkhand was positively correlated with all its three components however, non significantly with accessibility. Based on their findings they opined that the overall region is critically insecure; however only Jalaun district recorded high food security. Availability of food and livestock and higher consumption of fertilizer with adequate irrigational facilities accompanied by higher productivity of the crops were responsible factor for high food security of the district.

In a more recent study carried out in Phek district of Nagaland, Sahu *et al* (2017) measured the food security status of tribal people residing in remote rural villages. Based on the requirements and relevance of region, food security index had been developed using six area specific indicators viz., household dietary diversity score (HDDS), food consumption score (FCS), coping strategy index (CSI), self assessed food security (SAFS), household food insecurity access scale (HFIAS) and household hunger scale (HHS).

Nevertheless, assessing food security status facilitates the understanding of loopholes in the current policy orientation of the government; however, sustainability of the food security has emerged as prime concern in recent scientific literature. UNEP (2012), Hanson (2013), Lang and Barling (2013) reported its importance as fifth dimension of food security. Berry *et al* (2015) attempted to correlate the three dimensions of sustainable development i.e. economic, social and environmental with the pillars of food security. Economic sustainability is mandatory for adequate access to food, while social sustainability is determinant for both food access as well as utilization. Within the environment, adapting and mitigating climate change, and sustainability of natural resources is a pre condition for regular and sufficient food availability for all.

Vepa *et al* (2004) developed an atlas of the Sustainability of Food Security in India promoting ecologically sustainable methods of food production and natural resources

management. They examined the ability of Indian states to provide present food security as well as future sustenance to its people through *sustainable food security indices* prepared following the indicator based approach. On the basis of availability and reliability of data, a total of seventeen indicators were selected and grouped as indicators of sustainable food availability, sustainability of food access and food absorption. Indicators were assigned weights through principal component analysis (PCA) technique and aggregated into *sustainable food availability index*, *sustainable food access index* as well as *food absorption index*. It was observed that Northern states like Punjab and Uttar Pradesh; Madhya Pradesh and Rajasthan performed well in present security of food availability, whereas Kerala and north eastern states were ranked lower in the same category. It is worth mentioning here that the state of Punjab which topped in present food availability list, ranked at the bottom in the sustenance of food availability index category due to over exploitation and degradation of natural resources in the state. Further, the state of Madhya Pradesh and Arunachal Pradesh were leading in *sustainable food availability index* as these states are endowed with ground water resources and large forest areas; and following cereals –legume cropping pattern in their agricultural practices. More interestingly, the state of Uttar Pradesh and Punjab fell into *moderately unsustainable* and *unsustainable* category, respectively. Likewise, all states were separately ranked and categorized based on their index value of *present security* and *sustenance* and a composite *sustainable food access index* were constructed. Overall, the state of Arunachal Pradesh ranked highest in *sustainable food security index* followed by Madhya Pradesh. Most of the southern states barring Tamil Nadu; and Uttar Pradesh described as moderately sustainable, Punjab as moderately unsustainable and Nagaland was extremely unsustainable.

The fifth dimension of food security i.e., sustainability, have also been used in regional level studies in India. In a state level study carried out in Punjab, Nasir *et al* (2014) developed a composite index to measure sustainability of food system assuming its three components, namely availability, access and utilization. The authors used 19 indicators pertaining to these components for a comprehensive period of 1970-71 to 2009-10, which were assigned weights following Iyengar and Sudarshan method. They observed a marked and continuous improvement in the sustainability of food system in the state; however, one-third of the districts showed the potential for improving the availability component. Also, they opined that the access to food could be improved in one-fifth of the districts of the state. The study further concluded that, while the availability can be improved by reducing the yield gaps, generation of additional employment opportunities can help in increasing access to food through enhanced incomes. Improvement in literacy and health services were reported to improve the utilization of food.

Significance of sustainability parameter is not only limited to food security literature

but has also attained due consideration in other agricultural and economic studies. For example, Bharati and Sen (1997) examined agricultural sustainability of districts in Indian state of Bihar. In a more recent study, Kareemulla *et al* (2017) assessed the agricultural sustainability of 19 Indian states based on economic, ecological and social parameters for two different time periods 2000-2001 and 2010-2011. In another study of similar nature, Hatai and Sen (2008) developed *Sustainable Livelihood Security Index (SLSI)* of all districts of Odisha.

Knowledge gap

The available literature clearly indicates that numerous studies have been carried out to analyze the growth rates in area, production and productivity of agricultural crops at national as well as regional level in different time periods. However, most of the studies have been by and large focused in comparing the performance of agricultural production and productivity in pre and post-green revolution period. Although few studies covered a more recent period up to 2010-11 in presenting agricultural growth trend, the present study is a humble attempt in analyzing the same with more updated time scale i.e., TE 1990-91 to TE 2016-17.

Apart from food production, the procurement and distribution of food grains has direct impact on the food security of vulnerable sections of the nation. Therefore for better policy formulation it is imperative to look at the entire system of food production, food procurement and the release and distribution of food. Limited studies has been conducted regarding trend analysis of procurement and distribution of food grains at national level; and more specifically no study has been undertaken to present the distribution scenario of food grains in past few decades. In an advancement from the previous studies in national interest, the present study has given due emphasis on recent decadal trends of procurement and distribution of rice and wheat at national level.

As the regional trend of agricultural growth is bound to be different from national scenario, various studies have been undertaken in assessing growth of area, production and productivity of crops at more disaggregated level over the time. As reviewed, few studies in this context presented the agricultural growth scenario in the state of Punjab and Uttar Pradesh (Gulati *et al* 2017, Verma *et al* 2017) which is also the area of interest of the present study. However, none of the studies at regional level analyzed the rate of change in the growth rate over the time. It is worth mentioning here that trends in area, production and productivity of crops reported in earlier studies presents constant rate of growth of the considered parameters over the time. As growth is seldom unidirectional, capturing rate of change in the growth rate over the time through quadratic model more clearly depicts instantaneous increment or decline in growth rate over the specified time (Holt 2008). The present study critically emphasized the acceleration and deceleration of agricultural growth parameters viz., area, production and yield of crops, in the study area over the period under

consideration.

Therefore, the present study is an improvement over the previous studies in presenting the crop wise agricultural performance in world's most intensely farmed area i.e. Punjab and UP in a more recent time period i.e., TE 1990-91 to TE 2016-17 and rate of change in the growth rate within the period under consideration.

Through the literature review in assessing the food security, it is brought out that indicator based approach has been largely followed across the globe as well in Indian context in constructing food security index. However, most of these studies have confined their focus to the present security and have completely overlooked the future sustenance issue i.e. sustainability component of the food security. Also indicators considered for constructing the food security index in the previous studies were very specific and limited in number. Livestock component which has the crucial role in ensuring the food security of rural India has been completely ignored in earlier literature. More importantly, in almost all the previous studies the changing climatic parameters, which have now unanimously reported to increases the threat of food insecurity, didn't find any place in constructing the indices of food security.

The present study is pioneering in its attempt to present the updated sustainable food security status in the most populous and productive agricultural ecosystems in the country as well as in the world – *Punjab* and *Uttar Pradesh,* by capturing a wide range of regional indicators (the total number of indicators being 29) with due consideration of livestock sector and climatic factors as important indicator.

CHAPTER III

MATERIALS AND METHODS

The aim of this chapter is to provide the details of the data and methodological framework used to achieve the objectives of the study. The chapter is delineated into three sections. The first section presents the coverage of the study area, second describes the detail of the database used and the third section outlines the detailed analytical framework for achieving the three objectives of the study.

3.1 Geographical Coverage

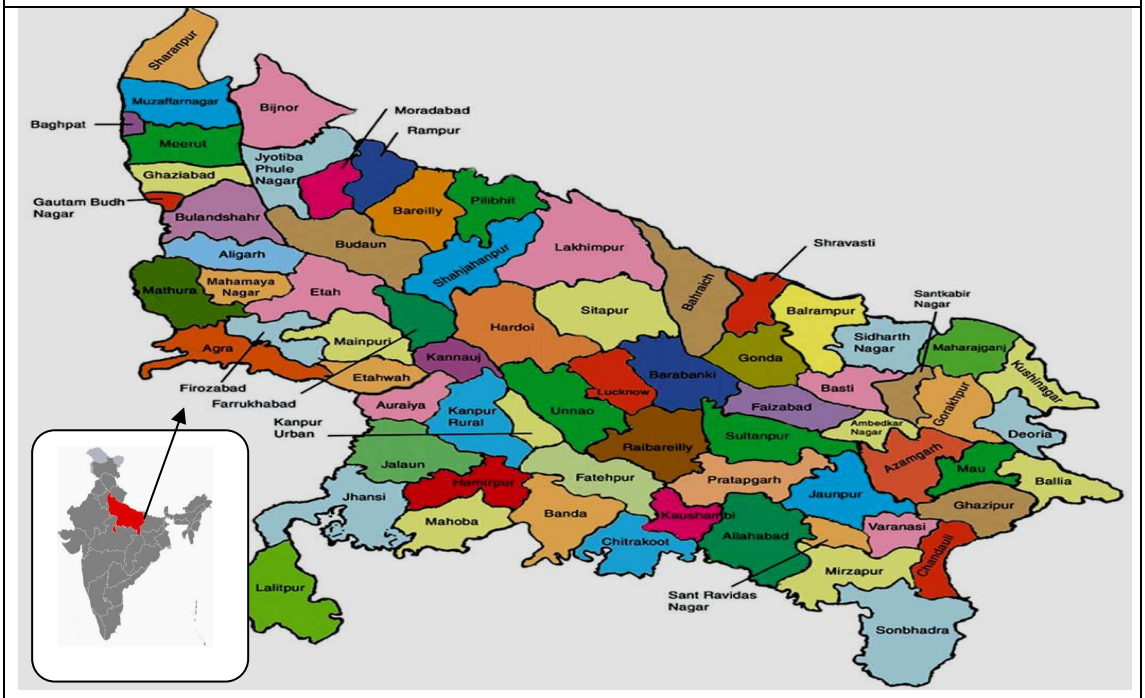
As mentioned earlier, the study has been conducted in the two Indian states i.e., Punjab and Uttar Pradesh which has been one of the epicenters of green revolution in the country. As per the agro-climatic distribution of zones made by Planning Commission of India based on a higher degree of commonality in the agro-meteorological characteristics of regions across the country, the states of Punjab and Uttar Pradesh falls in the Trans Gangetic Plains (agro-climatic zone 6) and Upper Gangetic Plains (agro-climatic zone 5), respectively (Khanna 1989).

Punjab which has gained recognition as the 'land of five rivers', is located in north-western part of India (Map 1a) and is spread in around 50 thousand square kilometre area. The latitudinal and longitudinal extension of the state covers 29.30 degrees north to 32.32 degrees north and 73.55 degrees east to 76.50 degrees east respectively. The major portion of the state has plain topography consisting of mainly fertile alluvial soils. The climate of the state is characterized by arid, semi-arid and sub-tropical conditions in different districts; but in general, Punjab has balanced amalgamation of continental weather with hot summer and cool winter. Rainfall in the state varies from around 200 mm in plains to 1150 mm in sub-mountain regions and about 80 per cent of it is received between June and September. The extensive canal system is an important source for irrigation in the state. The soil and climate characteristics of the state with assured irrigation favours rice-wheat cropping pattern as a most profitable combination of crops. Agricultural development in this region has witnessed a phenomenal increase in agricultural productivity ranging from 2 to 4 fold in most areas falling under this zone. The quantum jump in agricultural production and productivity in the aforesaid region is popularly known as Green Revolution.

The state of Uttar Pradesh is located in northern part of India (Map 1b) encompassing around 2 lakh square kilometre area. The state can be delineated into three hypsographical regions. The first is the Himalayan region in the north with extremely rugged and varied terrain. The second is the Gangetic Plain in the centre with highly fertile alluvial soils and a flat landscape which makes the region suitable for intensive cultivation. The third and last is the Vindhya Hills and Plateau region in the south characterized by hard rock strata and a diverse topography of plains, hills, valleys and plateau.

Map (1a) Punjab

Map (1b) Uttar Pradesh



Source: Census of India, 2011

The state of Uttar Pradesh is characterized by semi-arid and sub-humid climatic conditions. The mean annual rainfall varies between 700 and 1,000 mm. The major rivers of the state are the Ganga, Yamuna, Ghaghara and Sarayu, which bears a lot of agricultural as well as spiritual importance. The lead crops in Uttar Pradesh are rice, maize, bajra, jowar and arhar during *Kharif* and wheat, barley, rape-mustard, potato and gram in *Rabi* season. Uttar Pradesh is the leading sugarcane producing state of India with around 50 per cent share in

total cane area of the country. Due to its fertile soil and hospitable climate for farming, the state ranks among the world's most densely populated areas (Choudhary 2017).

In keeping with the approach followed by Planning Commission, the present study has been conducted at district level in the two states. This is particularly important, as districts are the lowest administrative unit at which reliable agricultural data is available. However, number of districts has changed over the time across the study area. The total number of districts in Punjab was 12 in the year 1990-91 which increased to 22 in the year 2012-13. Similarly, the total number of districts in the present Uttar Pradesh was 54 in the year 1990-91 which increased to 75 in the year 2012-13. At various point of time new districts were created either through bifurcating single district or partitioning two or more districts. For example, in Punjab in the year 1992-93, a new district Mansa were carved out from Bhatinda, whereas in the same year a new district Fatehgarh Sahib were formed by partitioning the three districts of the state namely Patiala, Ludhiana and Ropar. Similarly other new districts were created across the both the states during the study period under consideration (Annexure –I).

The changes in district boundaries poses challenges in preparing uniform district level time series data set. Therefore, following Choudhary (2017), district boundary adjustment was done for partitioned districts of both the states. District boundaries are usually adjusted considering either later or earlier years of the period in question as a base. In the present study, the old districts were furcated into newly created districts considering the year 2016-17 as base. The districts carved out from two or more districts were adjusted by providing population weights that permits easy construction of panels as suggested in most of the prior standard studies like Murthi *et al* (2001), Banerjee and Iyer (2005), Kumar and Somanathan (2009) on mapping Indian districts during different census years.

3.2 Dataset

The present study has been conducted using secondary data from various published and unpublished sources. The data pertaining to area, production and productivity of food grains (paddy, wheat, nutri cereals, total cereals and pulses), land holdings and demographic parameters, livestock parameters, climatic parameters and other variables were required for the study. The information on area, production and productivity of food grains was required for a comprehensive period of 1990-2017, however, data regarding other variables were taken only for the latest year as per the requirement of objective of the study i.e., construction of sustainable food security index. The change in net sown area at district level was one of indicators of food availability and thus its data for last 10 years were gathered. The detailed information on the variables and its relevant sources is discussed as below:

3.2.1 Area, production and productivity of food grains: The data pertaining to area under food grains (rice, wheat, nutri cereals, pulses, total cereals) and their production at national level as well as for the present study area viz., the state of Punjab and Uttar Pradesh, were

collected from publications of the Directorate of Economics and Statistics, Ministry of Agriculture and Farmer's Welfare such as Agricultural Situation in India and Agricultural Statistics of India as well as from directorate website from 1997 onwards. District wise data regarding total geographical area, net sown area, gross cropped area, net irrigated area were used to calculate the cropping intensity and irrigation intensity. The data of total forest cover, barren and un-culturable land, and culturable waste land were accessed from directorate website.

3.2.2 Land holdings and demographic parameters: District wise data regarding average size of holding and number of small and marginal farmers for the year 2015-16 were collected from Agricultural census, which is conducted every five years.

Data related to total population and rural population of each district falling in the states of Punjab and Uttar Pradesh were obtained from Population census, 2011. The district wise data for household industry workers and other workers which collectively constitute as non-agricultural workers; non-workers as well as total workers were also collected from Population census, 2011. The information on the number of households and number of landless labour households was compiled from Socio-Economic & Caste census, 2011. Data pertaining to non-crop agricultural workers for every district were obtained from the latest (2012-13) available Economic Census of the respective states.

3.2.3 Livestock parameters: District wise data on total livestock population of crossbred, indigenous cattle and buffalo were collected from 19th Livestock census (2012) published by the Department of Animal Husbandry, Dairying and Fisheries, Government of India. The milk production data of each district for the year 2014-15 were sourced from the report of National Dairy Development Board (NDDB).

3.2.4 Climatic parameters: The study has used district wise daily mean temperature at a spatial resolution of 0.5×0.5 degree and daily mean rainfall at a spatial resolution of 0.25 ×0.25 degree for the period 1980-2009 which were sourced from India Meteorological Department (IMD), Pune.

3.2.5 Other variables: The data pertaining to district wise consumption of NPK fertilizers were obtained from Fertilizer Statistics, published by The Fertilizer Association of India for the year 2015-16.

The district wise data showing unexploited ground water for future use for the year 2011 were sourced from Central Ground Water Board, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India.

The data on female literacy rate, infant mortality rate, percentage of population having access to safe drinking water, availability of health infrastructure (Sub centre, Public Health Centre, Community Health Centre, Sub Divisional hospital, District hospital) were generated from Census of India, 2011.

3.3 Analytical Framework

3.3.1 Growth performance and distribution of food grains at national level

The compound annual growth rate (CAGR) of agricultural crops provides the trend in growth over a period of time (Dandekar 1980, Singh and Rai 1997, Deosthali and Chandrahekhar 2004, Shadmehri 2008). The CAGR of area, production and productivity of crops over a comprehensive period of TE1990/91 - TE2016/17 and for the three decadal periods viz., TE1990/91-2000/01, TE2000/01-2010/11 and TE 2010/11-2016/17 at national level was estimated as follows.

$$Y_{it} = Y_0(1+r)^t \quad \text{.....(1)}$$

Where,

Y_{it} = Area / production / productivity of i^{th} crop at all India level in 't' time period

i = Paddy, Wheat, Nutri cereals, Total cereals, Pulses, Total food grains

t = TE1990/91-2000/01, TE2000/01-2010/11, TE2010/11-2016/17, TE1990/91-2016/17

Y_0 = Constant

r = Average compound growth rate per annum

Taking natural logarithm of equation (1) on both the sides,

$$\ln Y_{it} = \ln Y_0 + t\ln(1+r) \quad \text{.....(2)}$$

On putting

$$\ln Y_0 = \beta_1 \quad \text{.....(3)}$$

$$\ln(1+r) = \beta_2 \quad \text{.....(4)}$$

Equation (2) can be written as

$$\ln Y_{it} = \beta_1 + \beta_2 t \quad \text{.....(5)}$$

Therefore the model specification for estimating the CAGR will be

$$\ln Y_{it} = \beta_1 + \beta_2 t + \varepsilon \quad \text{……(6)}$$

and,

$$\text{CAGR\_Y}_i = \text{antilog}\ (\beta_2 - 1) \quad \text{.....(7)}$$

Where,

CAGR_Y_i is the compound annual growth rate of area / production / productivity of i^{th} crop.

3.3.2 Growth performance of food grains at regional level

The growth estimation of crops at regional level has been carried out by following model

$$\ln Y_{ijt} = \beta_1 + \beta_2 t + \varepsilon \quad \text{……(8)}$$

and,

$$\text{CAGR\_Y}_{ij} = \text{antilog}\ (\beta_2 - 1) \quad \text{.....(9)}$$

Where,

Y_{ijt} = Area / production / productivity of i^{th} crop in j^{th} state in 't' time period

i = Paddy, Wheat, Nutri cereals, Total cereals, Pulses, Total food grains

j = Punjab and Uttar Pradesh

t = TE1990/91-2000/01, TE2000/01-2010/11, TE2010/11-2016/17, TE1990/91-2016/17

As briefly mentioned in the review of literature, taking the clue from Boyce (1986), the acceleration and deceleration in the growth rates over each time period was estimated using the following log-quadratic model:

$$\ln Y_{ijt} = a + bt + ct^2 + u_t \quad \text{.....(10)}$$

Where, estimated value of *c* gives the measure of acceleration or deceleration.

If *c* is significantly positive it indicates acceleration, significant negative value shows deceleration in growth rate and insignificant value implies stagnation in growth process (Ghosh 2010).

The growth rate from equation (10) was derived as follows:

$$G(t) = \left(1/Y_t\right) * \left(dY_t/Y_t\right) \quad \text{.....(11)}$$

And thus,

$$G(t) = b + 2ct \quad \text{.....(12)}$$

First derivative of equation (12) with respect to time measured acceleration or deceleration in growth rate.

$$dG(t)/dt = 2c \quad \text{.....(13)}$$

If b > 0 and c > 0, growth rate is increasing over time.

While when b < 0 and c > 0, growth rate may be negative but accelerating provided t > $-b/2c$.

Now, b > 0, c < 0 indicates falling growth rate.

And finally, b < 0 and c < 0, implies deceleration in growth rate.

The inclusion of time squared term on the right hand side of equation (10) gave rise to the problem of multicollinearity. This is avoided by the normalization of time in mean deviation form, that is, by setting t = 0 at the midpoint of the series and this allows the time (t) and its square (t^2) to become orthogonal (Boyce, 1986). As it is further pointed out by Boyce (1986) that the normalization of time affects only the estimate of b (coefficient of t), the estimate of c (coefficient of t^2) remains unaffected with respect to the normalization.

3.3.3 Sustainability of food security

Though there are different methods to assess the food security of households at national level, however the construction of composite index of food security giving due importance to each of its components is more appealing. In the present study, composite index

of food security has been constructed from its components – food availability, access and utilization to assess the food security as well as its sustainability at district level in the two states of Punjab and Uttar Pradesh for the year 2015-16.

Food availability refers to amount of food that is present in a nation or area through domestic production, imports and food stocks. Food access refers to the ability of a household to acquire adequate amount of food through combination of purchases, borrowings or food assistance. Since these two components are not enough on their own as people need to be assured of safe and nutritious food to meet their dietary need which is met through food utilization.

Various steps followed in the study to assess the sustainability of food security are described under following sub-headings:

3.3.3.1 Selection of indicators

In the present study the three dimensions of food security – availability, access and utilization - were represented through a number of indicators describing the key issues related to each of its component. Since sustainability of food security has been the focus of study therefore the indicators for food availability and access were divided into two sets – one set of indicators deals with present security and other with future sustenance. For food utilization, only present security has been taken into consideration. The indicators and its relation with each component of food security were selected from wide range of indicators used in previous standard studies and discussion with experts. Table 3.1 gives the glimpses of indicators and their relation with each component of food security i.e., availability, access and utilization.

Food availability: A total of thirteen indicators affecting the agricultural production system were selected to represent the food availability since it is the function of food production. Out of total indicators, seven indicators, viz., cropping intensity, change in net sown area, food grain production per capita, irrigation intensity, fertilizer consumption, population density and milk productivity are pertaining to present security and other six indicators - per capita forest cover, unexploited ground water for future, degraded area to geographical area, leguminous crops in gross cropped area, growth rate of annual mean temperature, coefficient of variation of monthly mean rainfall represents future sustenance.

Cropping intensity is the raising of a number of crops on the same field during one agricultural year and is expressed as a ratio of gross cropped area to net sown area. This indicator is positively related to food availability i.e., higher the cropping intensity, higher will be the food availability in a region.

Change in the net sown area is considered as an important indicator for food availability as the districts where net sown area is expanding over time is better off in respect of present food security and vice-versa.

Food grain production per capita represents net availability of food to each and

every individual and is basic for achieving the security of food and is measured as total food grain production of a district divided by its population. The districts with higher per capita net availability of food are more secure in relation to those having less availability.

Irrigation intensity is expressed as a ratio of net irrigated area to net sown area. It affects the food availability by contributing to the growth in the overall cropping intensity of a region. Therefore, the indicator positively influence the food availability in a region i.e., the districts with higher irrigation intensity have more availability of food and are more food secured.

Since higher ***fertilizer consumption*** augments the food production, the districts with higher consumption of NPK fertilizes are taken as more food secure. ***Milk productivity*** also bears positive relation with food security of the region. Contrarily, ***population density*** has been defined as the number of persons per square kilometer and negatively affects the food availability of the region.

Per capita forest cover measures human pressure on forest and is calculated by dividing the total forest area of a district with its population. This indicator reflects the natural resource endowment of a region useful for further agricultural production by preserving its watersheds and thus has been included as a positive indicator of sustenance of food availability. Likewise, the districts with higher ***unexploited ground water for future use*** are considered to be more sustained in terms of food availability and thus more food secured for future generation.

Further, ***degraded area to geographical area*** is calculated by dividing the area under degraded land to total geographical area. Degraded land consists of barren and un-culturable land and culturable waste land. Barren and un-culturable land are those which cannot be brought under cultivation except at an exorbitant cost, whether such land is in isolated blocks or within cultivated holdings and includes all land covered by mountains, deserts, etc. On the other hand, culturable waste land is the land available for cultivation, whether taken up or not taken up for cultivation once, but not cultivated during the last five years or more in succession including the current year for some reason or the other. Such land may either be fallow or covered with shrubs and jungles which are not put to any use (GoI 2014). This indicator negatively influences the sustenance of food production as the districts with smaller percentage of degraded land are regarded as more sustained in contrast to others which have higher percentage of same.

Percentage of ***leguminous crops in gross cropped area*** is measured as the ratio of area under pulses to the total cropped area. The legume crop helps in restoring the soil fertility with the adoption of viable cropping pattern, thus ensures the sustenance of food production. Therefore, the districts with the higher percentage of area under legumes are more food sustained and secured.

Table 3.1 Indicators and their functional relationship with sustainable food security

Component	Related with	Indicators	Unit	Relation with sustainable food security
Food Availability	**Present security**	Cropping Intensity	%	Direct
		Change in net sown area	%	Direct
		Food grain production per capita	kgs/month/ person	Direct
		Irrigation Intensity	%	Direct
		Fertilizer consumption (NPK)	Tonnes/ha	Direct
		Population density	Person/km^2	Inverse
		Milk productivity	MT/milch animal/year	Direct
	Future sustenance	Per capita forest cover	Hectare (ha)	Direct
		Unexploited ground water for future	Hectare metre (ham)	Direct
		Degraded area to geographical area	%	Inverse
		Leguminous crops in gross cropped area	%	Direct
		Growth rate of annual mean temperature	%	Inverse
		Coefficient of variation of monthly mean rainfall	%	Inverse
Food Access	**Present security**	Below poverty line population	%	Inverse
		Non agricultural workers to total workers	%	Direct
		Number of milch animals per 000' population	No.	Direct
		Cross bred adoption rate	%	Direct
		Small and marginal farmers per 000' population	No.	Inverse
		Non worker population	%	Inverse
		Buffalo : Indigenous Cattle ratio	%	Direct
	Future sustenance	Average size of holding	Hectare (ha)	Direct
		Livestock density	No./km^2	Inverse
		Non crop agricultural workers	%	Direct
		Landless labour households to total households	%	Direct
		Instability in cereal production	%	Inverse
Food Utilization	**Present security**	Safe drinking water	%	Direct
		Infant mortality rate	%	Inverse
		Health infrastructure	No.	Direct
		Female literacy rate	%	Direct

The changes in the climatic parameters i.e., temperature and rainfall, over the years affects the production and productivity of crops and thus must be considered as important indicator of sustenance of food production as well as its availability. Therefore, ***growth rate of annual mean temperature*** and ***coefficient of variation of monthly mean rainfall*** for the time slice of 30 years (1980-2009) were incorporated in the present study as an indicator of future sustenance of food availability.

Food access: The food access component of food security is related to the purchasing power of an individual which depends on income earned and is affected by number of indicators. Below poverty line population, non agricultural workers to total workers, number of milch animals per 000' population, crossbred adoption rate, small and marginal farmers per 000' population, non worker population and buffalo to indigenous cattle ratio determine the present security of food access; whereas future sustenance is affected by average size of holding, livestock density, non crop agricultural workers, landless labour households to total households and instability in cereal production.

Below poverty line and ***non worker population*** negatively affects the food access i.e., the population faces difficulty in purchasing sufficient food for their livelihood. ***Non-agricultural worker to total worker*** is the ratio of non-agricultural workers to the total workers. Non-agricultural worker include household industry workers and other workers. Household industry workers are those workers who are engaged in activities of production, processing, servicing, repairing or making and selling of goods and it does not include professions such as a pleader, doctor, musician, dancer, waterman, astrologer, dhobi, barber, etc. or merely trade or business, even if such professions, trade or services are run at home by members of the household. Other workers are defined as persons engaged in some economic activity during the last year of reference period but not as a cultivator or agricultural labourer or worker in household industry. All government servants, municipal employees, teachers, factory workers, plantation workers, those engaged in trade, commerce, business, transport, banking, mining, construction, political or social work, priests, entertainment artists, etc. fall under this category of other workers (Census 2011). This indicator positively determines the security of food access as higher percentage of it reduces the dependence on primary sector (agriculture) through a shift to the higher income secondary sector (manufacturing & industry). Therefore, the districts with larger percentage of non-agricultural workers have higher access to food and are more secured and vice-versa. Even the ratio of small and marginal farmers to the rural population which gives ***small and marginal farmers per 000' population*** is inversely related to food access security due to their low income and thus low purchasing ability.

Further, the livestock sector which is prime source of income along with crop cultivation for rural population can't be overlooked as food access is concerned. Larger

number of milch animals per 000' population and higher percentage of ***cross bred adoption rate*** as well as ***buffalo to indigenous cattle ratio*** in a district directly contribute to earnings of rural population, indicates higher food self-sufficiency and thus more food secure.

Average size of land holding facilitates adoption of modern technology on farm and thus increases income of the farm households. Therefore, it bears positive relation with the sustenance of food access. ***Livestock density*** negatively influence the food access sustenance as more livestock population put excess pressure on land due to overgrazing and thus results in degradation. ***Percentage of non-crop agricultural workers*** and ***landless labour households to total households*** contribute directly to security of future generation since they reduce the pressure on land and natural resources through diversification towards allied activities and thus improve the livelihood access for future. The ***instability in cereal production*** calculated by Cuddy-Della Valle instability index over 10 years is as follows:

$$Cuddy-Della\ Valle\ Instability\ Index\ (\%) = C.V * \sqrt{1-\bar{R}^2} \quad \ldots\ldots\ldots\ldots (14)$$

Where,

$C.V$ = Coefficient of Variation

$\bar{R}^2$ = Adjusted coefficient of determination

$$Coefficient\ of\ Variation = \frac{Standard\ deviation}{Mean} * 100 \quad \ldots\ldots\ldots\ldots (15)$$

The fluctuations in cereal production due to natural as well as man-made factors results in serious food access problem in the near future. Thus the districts with higher instability in cereal production are less sustained with respect to food access and those with less instability are more sustained.

Food utilization: Among the indicators of food utilization, districts with higher ***female literacy rate***, better ***access to safe drinking water***, significant ***health infrastructural*** development and low ***infant mortality rate*** are supposed to be in much better condition in context of absorption of food than that of other districts and thus are more food secured.

3.3.3.2 Normalization of indicators

As the indicators are measured in different units and scale, they are not additive. It becomes necessary then to convert them into some standard units to avoid any scale biasness in ultimate result. Various methods have been suggested in literature to normalize the influence of units and scale. These are ranking, standardization, min-max (subtracting minimum value from each observation and then dividing it by range of indicators values when it has positive relation; while in case of inverse relation, subtracting each observation from its maximum value and then dividing it by range of indicators values), proportionate, division by its length and division by its mean or any other ideal value. Each of them has its own merits and demerits though choice of any of these is not a value free decision.

In the present study, mean was used to transform the data matrix into a scale free matrix of indicators of each component of sustainable food security for two reasons:

(a) It does not affect the dispersion of indicators

(b) It satisfied the basic axioms.

3.3.3.3 Assigning weights to indicators and construction of Sustainable Food Security Index:

Since all the indicators cannot be of equal importance in explaining the sustainability of food security, they need to be attached different weights. Based on the past reviewed literature (Demeke *et al* 2011, Napoli 2011, Wineman 2014, Solaroli 2015) the 'Principal Component Analysis (PCA)' is supposed to be the most reliable method for assigning weights to the indicators while constructing food security index.

Therefore the present study has also used PCA technique to assign weights to indicators of each dimension of food security. Conceptually, PCA is a multivariate statistical technique for finding patterns in data of high dimension. Once the patterns hidden in data are identified, PCA helps to compress the data by reducing the number of dimension without much loss of information. In original data indicators may be correlated and PCA help to transform them into uncorrelated variables.

Taking clue from Choudhary (2017), following steps were used for calculating the weights through PCA and construction of indices for each dimension of food security:

Step- I : Compute $X = X'_s X_s$

$(k \times k) \quad (k \times n)\ (n \times k)$

Where, X_s (n x k) is the normalized data matrix, X'_s (n ×k) is the transpose of normalized matrix and, n and K are the number of observations (districts) and number of indicators used.

Step- II : Conversion of the array (**X)** into symmetric matrix.

Step –III : Eigen value decomposition of the symmetric matrix to get principal components.

Step – IV : Selection of eigen vectors corresponding to the largest eigen value i.e., first principal components say 'W (k x 1)' explaining the maximum variation.

Step –V : Compute $Y = X_s W$

$(nx1) \quad (nxk)\ (kx1)$

Step-VI : Construction of final index by dividing the Y with sum of the first principal components.

The above procedure was followed to construct separate indices for each component of sustainable food security viz., Index of food availability security, Index of food availability sustenance, Index of food access security, Index of food access sustenance and Index of food utilization (FUI).

The composite Sustainable Food Availability Index (SFAI) was constructed by combining weighted average of its two sub-indices i.e., Index of food availability security (FAI) and Index of food availability sustenance (FSI). Following Vepa (2004), the weight to each sub-index was assigned depending on their share in total indicators considered for respective composite index. Therefore, index of food availability security and Index of food availability sustenance obtained weights 0.55 and 0.45 and composite Sustainable Food Availability Index (SFAI) value was obtained as follows:

$$SFAI = FAI*0.55 + FSI*0.45$$

Similarly, the Sustainable Food Access Index (SFAcI) was constructed from the weighted average of its sub indices - index of food access security (FASI) with weight 0.60 and index of food access sustenance (FASUI) with weight 0.40 as:

$$SFAcI = FASI*0.60 + FASUI*0.40$$

Finally the Sustainable Food Security Index (SFSI) for each district (k) was calculated as weighted mean of the three composite indices viz., Sustainable Food Availability Index (SFAI), Sustainable Food Access Index (SFAcI) and Food Utilization Index (FUI).

$$SFSI_k = \frac{(W_1 * SFAI_k) + (W_2 * SFAcI_k) + (W_3 * FUI_k)}{\sum_{i=1}^{3} W_i} \qquad \text{..... (16)}$$

Where,

W_i is the weights assigned to respective components of SFSI.

A number of earlier studies based on indexing approach have used equal weightage technique to all the components of a composite index. It's a rather restrictive approach owing to the fact that relative importance of availability, access and utilization dimension varies across regions. Therefore, in the present study, different weights are calculated as the ratio of inverse of the proportional contribution of SFAI, SFAcI and FUI to the sum of all the three inverse proportions for the three components for each region and for each component across the regions (Chand and Sirohi 2012). Higher value of SFSI indicated higher security as well as sustainability of the region.

CHAPTER IV

RESULTS AND DISCUSSION

The results and discussion of the present study have been presented in detail in this chapter under the following major headings:

4.1 Growth performance and distribution of food grains at national level

4.2 Growth performance of food grains at regional level

4.3 Sustainability of food security

4.4 Policy implications for sustainable food security in India as well as for the selected states

4.1 Growth performance and distribution of food grains at national level

The compound annual growth rate was calculated following the semi-log model to examine the trends in growth rate in area, production and productivity of paddy, wheat, nutri cereals, total cereals, pulses and total food grains at national level over the comprehensive period of TE 1990/91 to TE 2016/17 as well as sub periods TE 1990/91-2000/01 (PI), TE 2000/01-2010/11(PII) and TE2010/11-2016/17(PIII). Also an attempt has been made to examine the trends in procurement as well distribution of rice and wheat during the same time period.

The present section has been organized into three sub-sections. The first sub-section presents the estimated trend in area of total food grains as well as discusses the area trend of cereals crops, total cereals and pulses. The second and third section deals with production and productivity trend of total food grains, cereals and pulses, respectively.

4.1.1 Trends in area

The average area under total food grains during the two and half decade period (1990/01 to 2016/17) was around 1240 million hectares (Table 4.1) however; the area under food grains has declined over the time (fig. 4.1). The long term trend also indicates significant decline in the area under food grains during the whole period due to slump in area under the total food grains during PI i.e., TE 1990/91 to 2000/01, with annual rate of around 1 per cent (Table 4.2). The year on year analysis depicts fluctuations in growth of area under the total food grains with sharp negative peak in the year 1991-92 (fig. 4.2).

The actual area under total cereals remain more or less stagnated (Fig. 4.3) however, trends in growth rate shows that it declined significantly at an annual rate 0.09 per cent from TE 1990/91 to TE 2016/17 (Table 4.2). The year on year fluctuations in growth of area under total cereals reveals a sharp fall in 2002-03 by 7 per cent followed by 4 per cent decline in 2004-05 (Fig. 4.4).

Among cereals, acreage under paddy has a lion's share i.e., around 43 per cent in total food grains followed by nutri cereals and wheat during the whole period (Table 4.1). The area

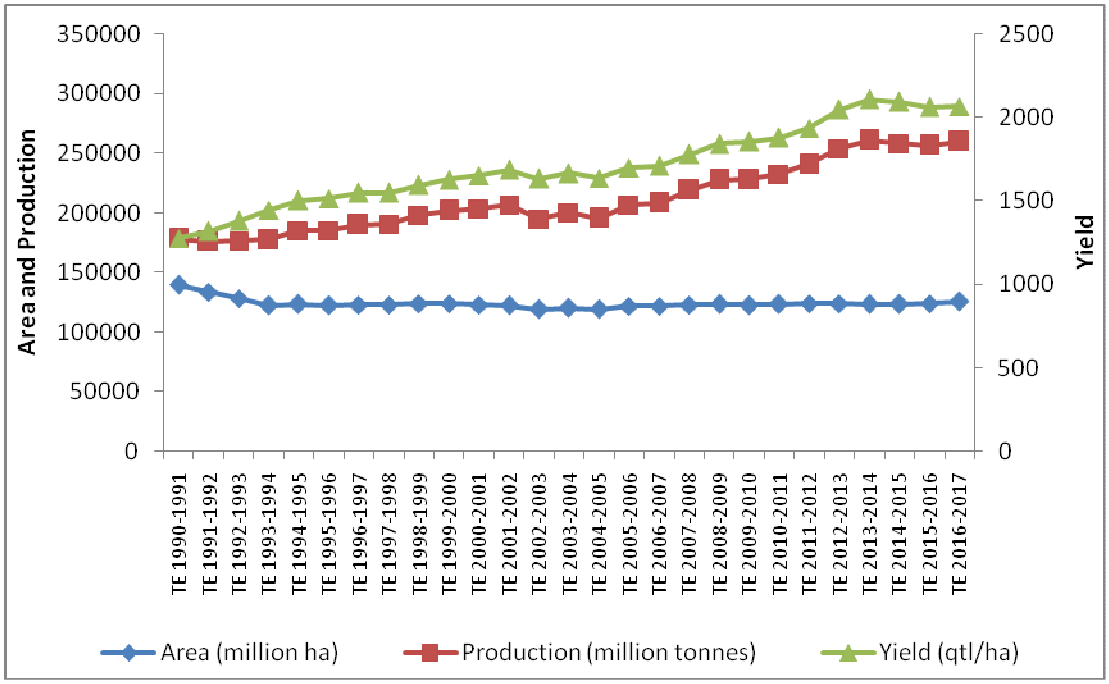


Fig 4.1: Area, production and productivity of food grains, TE 1990/91 to TE 2016/17

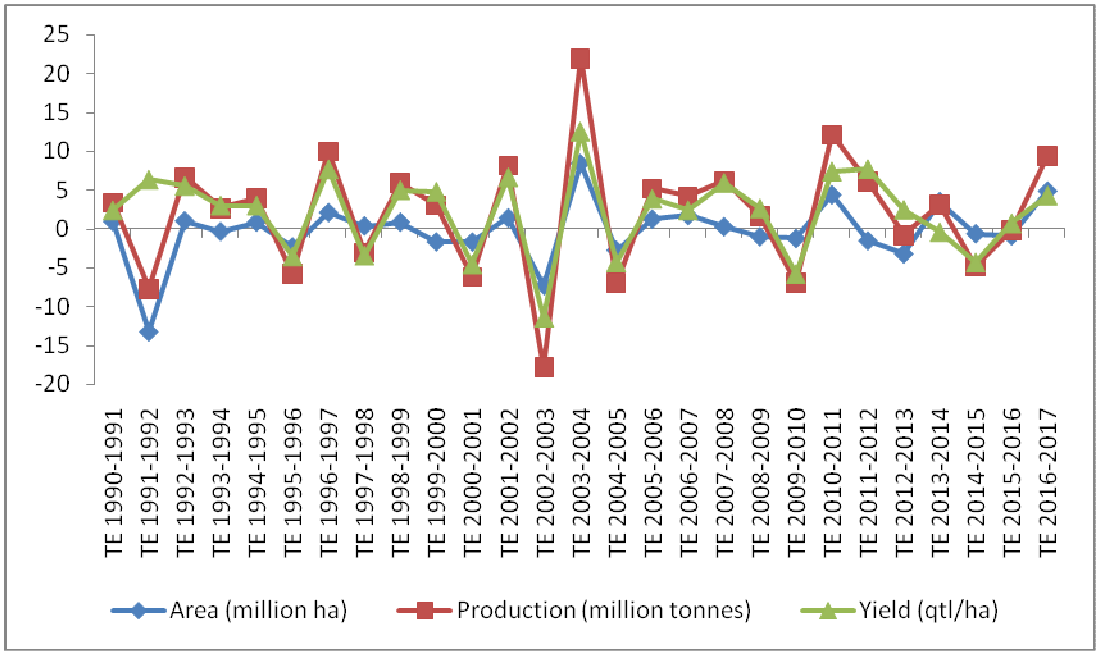


Fig 4.2: Triennium year on year growth of area, production and productivity of food grains

under paddy has significantly increased over the comprehensive period (CAGR 0.099 %) and during the two decadal periods viz., PI and PIII. During TE2000/01-2009/10, area under the crop declined, though non-significantly (Table 4.2). The year on year area growth depicts clear fluctuations in the area under paddy over the entire considered period with major negative peak in the year 2002-03 and 2009-10 (Fig. 4.6).

Table 4.1: Mean and standard deviation of area under crops for different periods

(*million hectares*)

Crops	**TE 1990/91 to TE 1999/00**	**TE 2000/01 to TE 2009/10**	**TE 2010/11 to TE 2016/17**	**TE 1990/91 to TE 2016/17**
Paddy	429.13 (7.57)	436.05 (9.78)	435.22 (3.57)	433.27 (8.15)
Wheat	251.57 (12.06)	268.25 (8.05)	299.47 (9.29)	270.17 (21.41)
Nutri cereals	330.19 (24.39)	289.72 (6.05)	260.16 (12.52)	297.04 (32.62)
Total cereals	1010.99 (11.14)	993.08 (13.98)	994.85 (1.76)	1000.17 (13.54)
Pulses	228.48 (4.84)	221.89 (7.31)	246.00 (6.82)	230.58 (11.49)
Food grains	1264.42 (58.61)	1216.71 (16.45)	1240.86 (7.45)	1240.64 (41.63)

Note: Figures in parentheses shows standard deviation

The average area under wheat over the comprehensive period was 270.17 million hectares and its decadal mean has continuously increased in all the three sub periods (Table 4.1). The noteworthy rise in area under wheat can also be noticed in Fig. 4.7. Among all the sub-periods and comprehensive period, area under the crop witnessed significant rise with prominent figure during PI and PIII (Table 4.2). Nonetheless, wheat acreage registered positive significant growth over the considered period under study, variation in the year on year growth has been also observed with marked decline in the growth of area under the crop by around 6 per cent in 2000-01, and by around 4 per cent in 1991-92 and 2002-03. In the recent past, growth in area under the crop also sharply turned down during 2015-16 (Fig. 4.8).

Although nutri cereals have second major share after paddy in area under total cereals, its area has slipped down in all the sub-periods over the previous period (Table 4.1) and thus over the overall period it depicts declining trend (Fig 4.9). The decline in area was significant during overall period and in all the three sub periods with maximum decline in period I (Table 4.2). Again the year on year growth in area under nutri cereals depicts that, although during maximum number of years the growth in area was negative, the year 2003-04 witnessed around 14 per cent growth in area under nutri cereals over the previous year (Fig. 4.10).

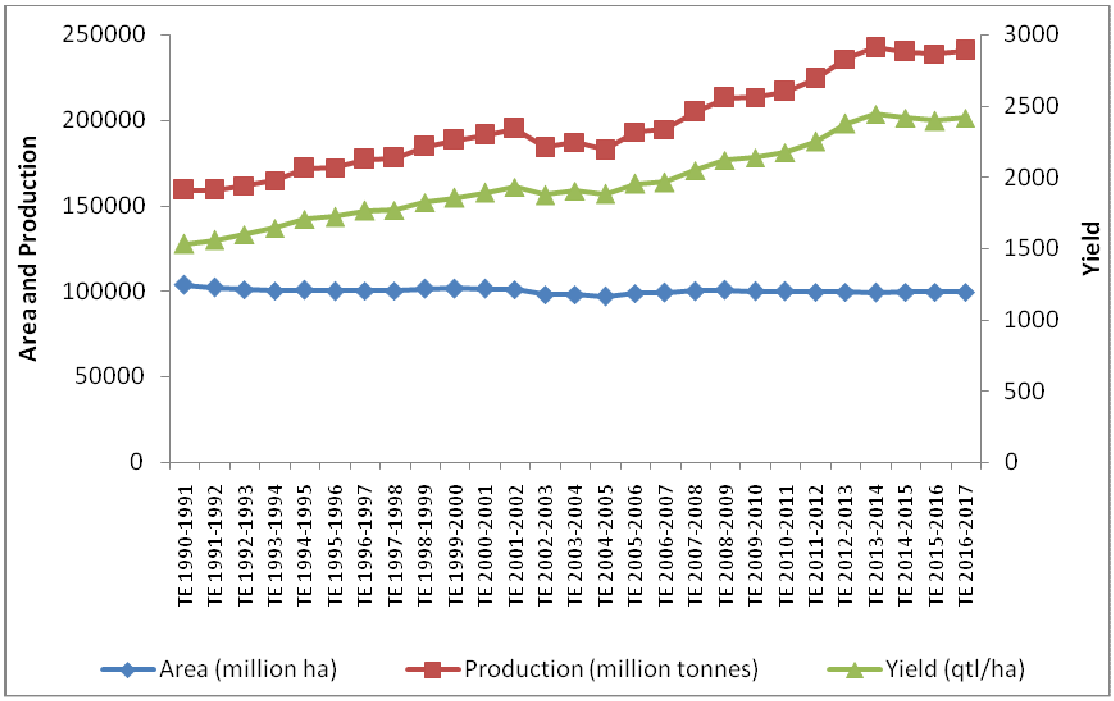


Fig 4.3: Area, production and productivity of total cereals, TE 1990/91 to TE 2016/17

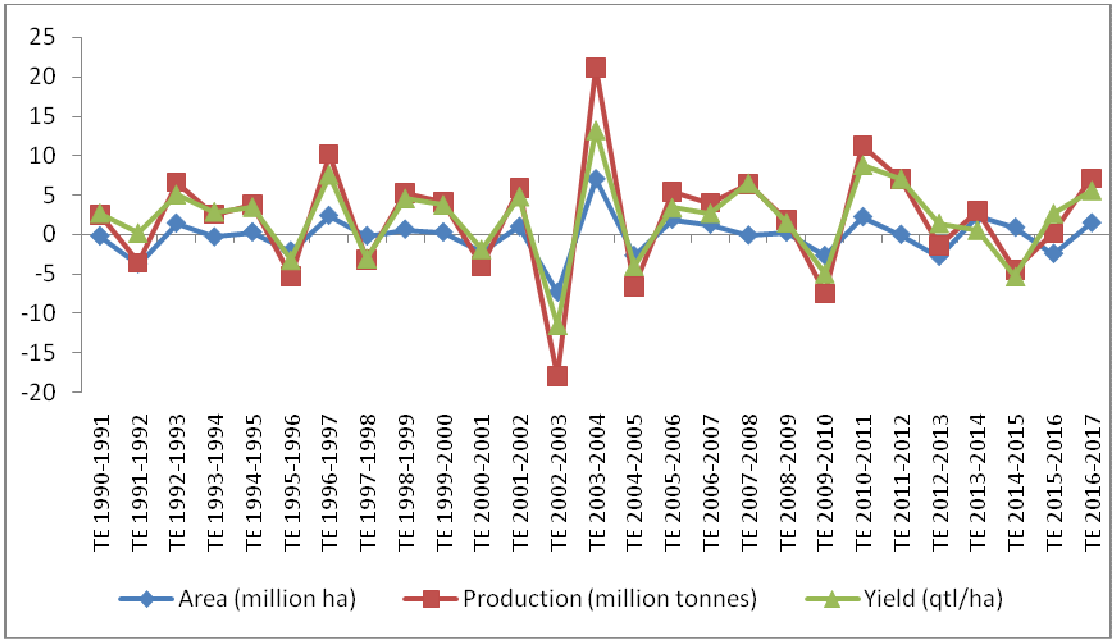


Fig 4.4: Triennium year on year growth of area, production and productivity of total cereals

Table 4.2: Growth rate of area of crops for different time period

Crops	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Paddy	0.520* (5.83)	-0.148 (-0.57)	0.305** (3.00)	0.099** (2.31)
Wheat	1.532* (12.24)	0.723** (3.04)	1.404* (8.89)	0.944* (15.86)
Nutri cereals	-2.367* (-15.84)	-0.571* (-4.11)	-2.106* (-7.16)	-1.314* (-19.00)
Total cereals	-0.171 (-1.52)	0.007 (0.03)	-0.001 (-0.03)	-0.093* (-3.27)
Pulses	-0.475** (-2.65)	0.946* (4.80)	0.729 (1.57)	0.324* (3.05)
Food grains	-1.092** (-3.06)	0.163 (1.11)	0.146 (1.38)	-0.155** (-2.06)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

The mean area under pulses declined by around 7 million hectares in PII over PI and then improved to around 246 million hectares in PIII (Table 4.1). The area has significantly increased with annual rate of 0.32 per cent over the entire study period, however, in sub period PI pulses registered significant decline in its area (Table 4.2). The year on year growth of area under pulses reveals that while annual growth in area was mostly below zero during 1990s, the crop registered marked improvement in its acreage in 2001/02 and 2003/04 during the sub period PII, and in 2010/11 during the PIII (Fig 4.12).

4.1.2 Trends in production

The average annual production of total food grains during the overall period was 2114.57 million tonnes (Table 4.3). The trend in the production of food grains shows an impressive and significant growth (CAGR 1.60 %) during the whole period as well as in the sub periods with the highest growth being registered in PIII (CAGR 1.70 %) (Table 4.4). Although, the year on year growth in food grain production was positive in almost all the years, a sharp decline of 18 per cent was observed in 2002-03 over the previous year (Fig. 4.2). The year of 2009-10, 2014-15 and 2015-16 also witnessed negative annual growth in total production of food grains. It is noteworthy to mention here that the above specified years in which food grains production registered below zero rate of growth was metrological drought year in India (GoI, 2017).

The total cereals also register splendid growth in the overall period as well as sub periods. It is important to mention here that although the area remains more or less stagnated, the actual production rises over the years (Fig 4.3) with significant annual growth rate of 1.65

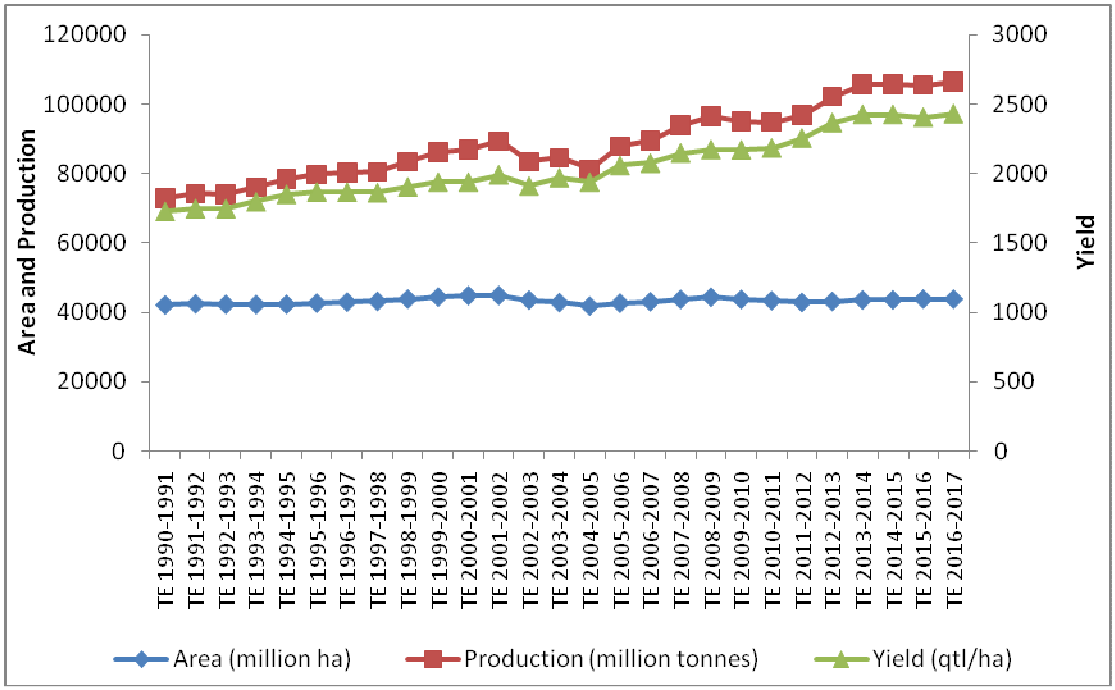


Fig 4.5: Area, production and productivity of paddy, TE 1990/91 to TE 2016/17

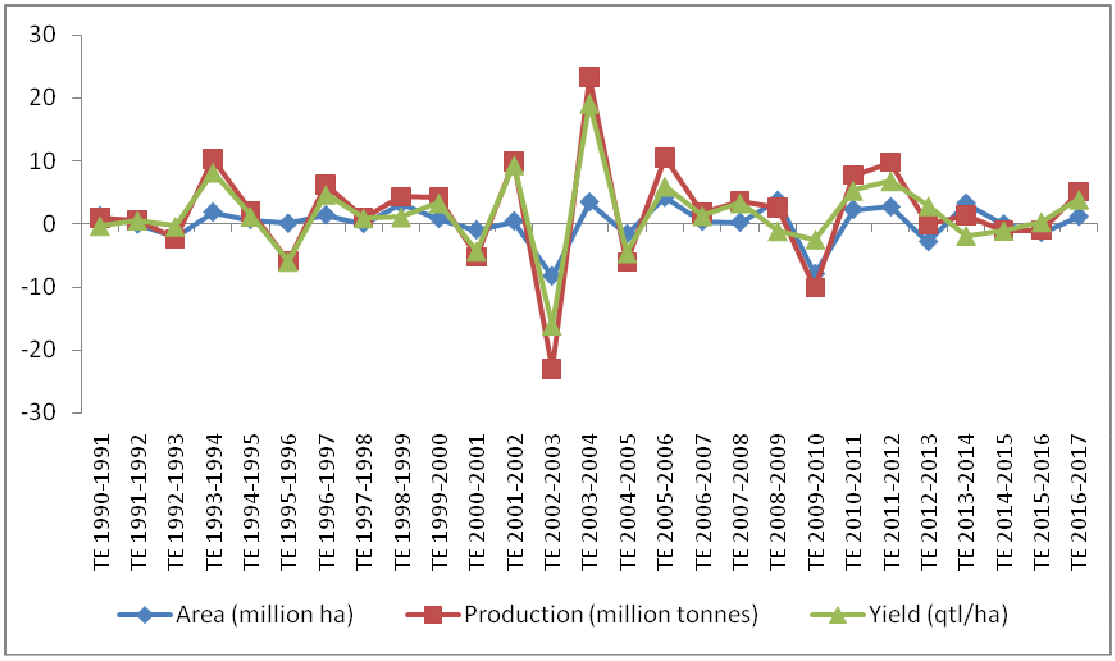


Fig 4.6: Triennium year on year growth of area, production and productivity of paddy

per cent (Table 4.4). Nevertheless, the production growth of total cereals was significantly positive in all the sub periods, the period PI marked maximum growth of around 2 per cent. As total cereals accounts for around 90 per cent in total food grains production, the above discussed year on year annual growth of total food grains production was mainly attributed to the total cereals production (Fig. 4.4).

Table 4.3: Mean and standard deviation of production under crops for different periods

(million tonnes)

Crops	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Paddy	785.02 (43.30)	887.94 (50.95)	1024.67 (48.20)	885.27 (105.75)
Wheat	615.69 (64.30)	727.46 (38.64)	903.95 (39.78)	731.82 (124.44)
Nutri cereals	314.17 (8.84)	338.87 (29.10)	410.85 (12.27)	348.39 (43.48)
Total cereals	1714.88 (103.90)	1957.66 (110.86)	2339.47 (98.09)	1966.73 (268.41)
Pulses	131.74 (2.91)	133.54 (9.48)	176.17 (10.46)	143.93 (20.92)
Food grains	1859.00 (91.85)	2089.40 (120.09)	2515.64 (108.06)	2114.57 (281.57)

Note: Figures in parentheses shows standard deviation

Table 4.4: Growth rate of production of crops for different time period

Crops	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Paddy	1.779* (14.52)	1.319** (2.75)	1.996* (4.64)	1.443* (19.03)
Wheat	3.443* (26.56)	1.118** (2.42)	1.512 (2.36)	2.070* (17.96)
Nutri cereals	-0.397 (-1.34)	2.635* (7.72)	1.080** (2.70)	1.344* (9.23)
Total cereals	1.971* (18.15)	1.403** (3.29)	1.648** (3.35)	1.651* (21.01)
Pulses	-0.165 (-0.65)	2.208* (7.44)	2.345** (3.41)	1.390* (6.75)
Food grains	1.538* (8.76)	1.485* (3.67)	1.697** (3.41)	1.582* (18.44)

*Significant @ 1%, ** significant @ 5 % level of significance

Note: Figures in parentheses shows two-tailed t-statistics value

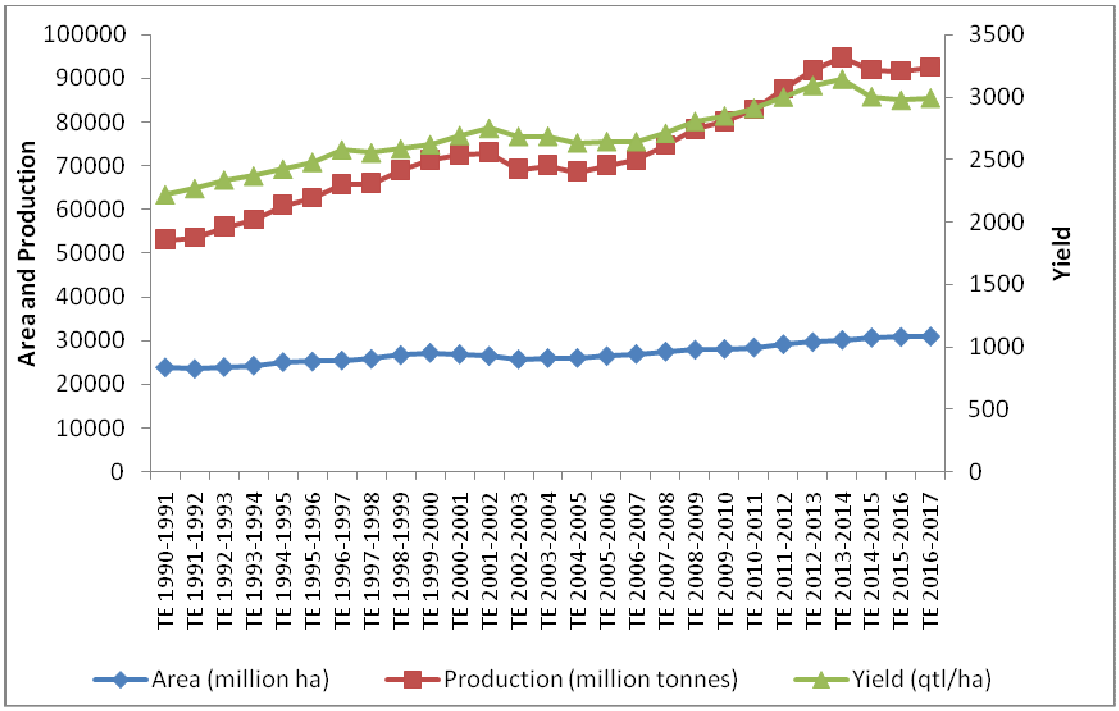


Fig 4.7: Area, production and productivity of wheat, TE 1990/91 to TE 2016/17

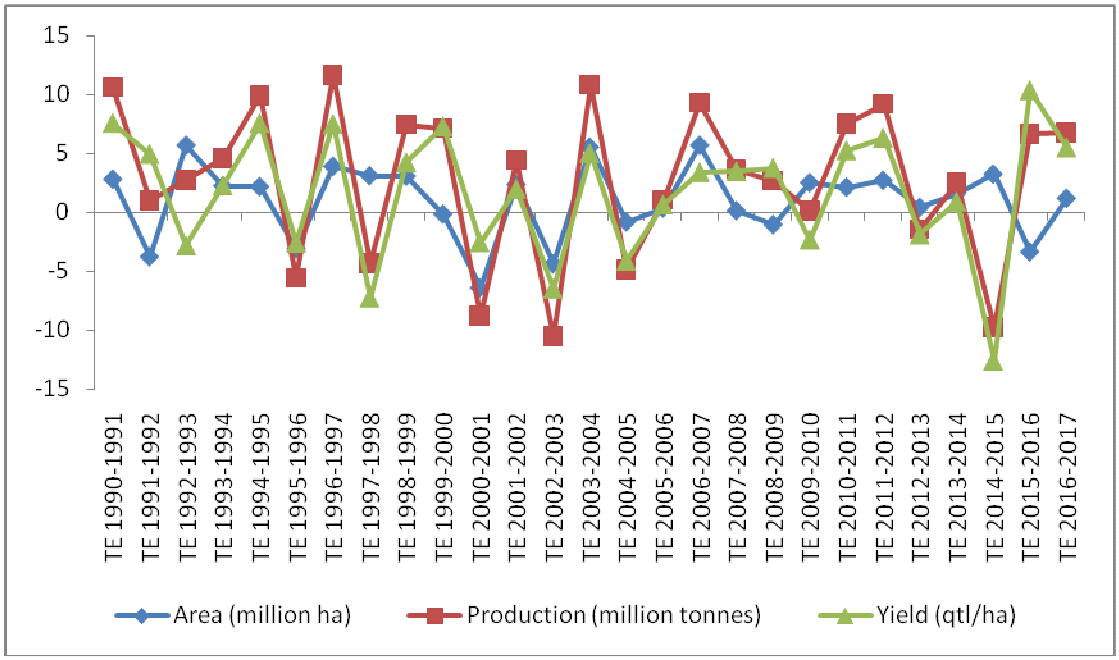


Fig 4.8: Triennium year on year growth of area, production and productivity of wheat

The crop wise analysis of cereals reveals that production of paddy, wheat and nutri cereals significantly increased during the entire study period, though the growth in production of nutri cereals was negative but non-significant during the period PI. The decadal growth rate as well as the average production is more profound in the sub period PIII in contrast to other sub periods. The variation in the year on year growth of paddy recorded lowest production in the agricultural year 2002-03 and has declined by 23 per cent in the given year (Fig 4.6). The trend in the production of paddy (Fig. 4.5) was comparatively smooth than that of the wheat (Fig. 4.7) and nutri cereals (Fig. 4.9).

The year on year growth analysis further reveals that the annual growth in wheat registered more upward and downward fluctuations (Fig. 4.8) than that of paddy (Fig. 4.6) and nutri cereals (Fig. 4.10).

The average pulse production during the whole period (143.93 million tonnes) was only around 7 per cent of total food grain production (Table 4.3). The pulses production registered splendid improvement after 2000/01, as the production increased significantly at an annual rate of more than 2 per cent in sub periods PII and PIII contrary to the negative growth in PI (Table 4.4). The upward production trend of pulses can also be noticed from fig 4.11. Although pulses witnessed year on year wide fluctuations in its production growth, it registered marked positive growth in the year 2003-04 and 2016-17 as area under pulses also noticeably increased during that period (Fig 4.12).

4.1.3 Trends in productivity

The average productivity of total food grains has seen an impressive growth over successive decades and the average yield for the overall period was around 17 qtl per hectare (Table 4.5). The productivity growth was also positive and significant during the entire study period and also in all three sub periods; however the growth was more robust during PI (Table 4.6). Nevertheless, the year on year productivity growth was positive for most of the years during the study period, it registered marked negative growth figure during drought years i.e. 2002-03, 2009-10 and 2014-15 (Fig 4.2).

The productivity growth of total cereals was similar to that of total food grains, however, crop wise analysis depicts quite interesting productivity scenario over the time.

Although productivity of paddy, wheat and nutri cereals has significantly increased over the entire study period; the productivity growth of wheat was more robust in PI than other sub periods, while in case of nutri cereals it remarkably crossed the rate of 3 per cent in PII and PIII (Table 4.6). The year on year growth analysis of the above three cereals crops largely presents similar fluctuations over the year, though with different magnitude.

The highest dip in productivity growth for paddy was around 16 per cent noticed in year 2002-03 (Fig. 4.6), while in case of wheat productivity declined as low as by 12 per cent in 2014-15 (Fig. 4.8). This decline was mainly due to weather abnormalities and bad monsoon

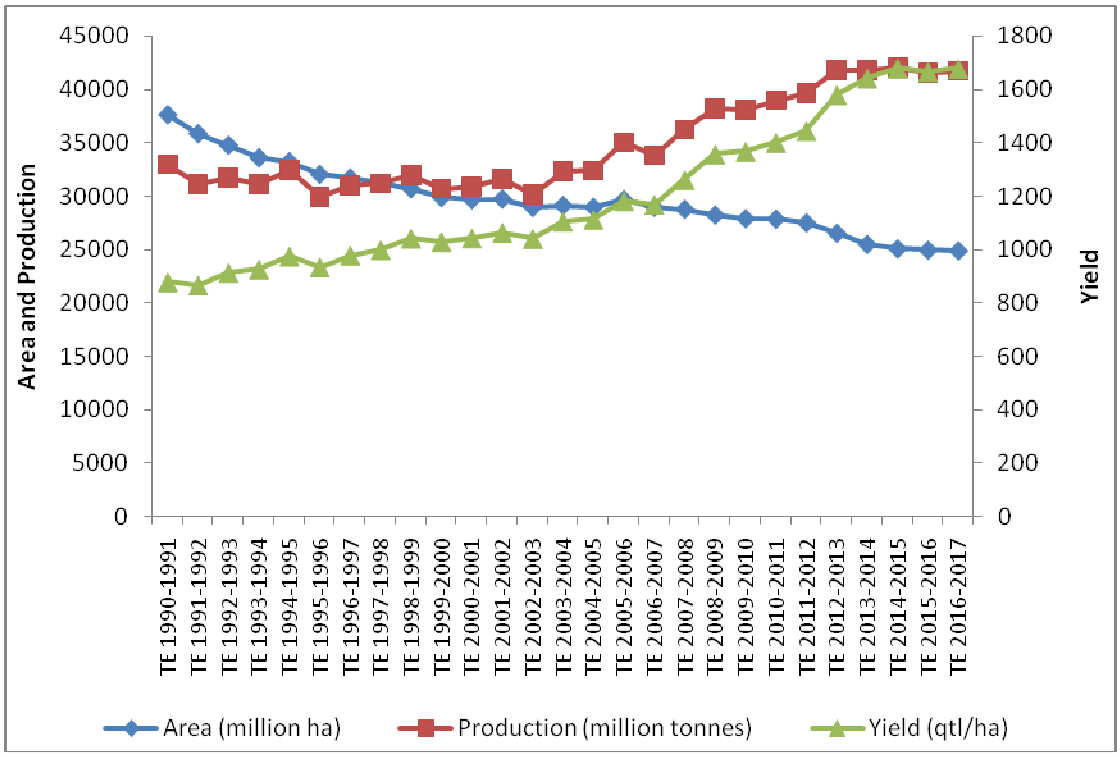


Fig 4.9: Area, production and productivity of nutri cereals, TE 1990/91 to TE 2016/17

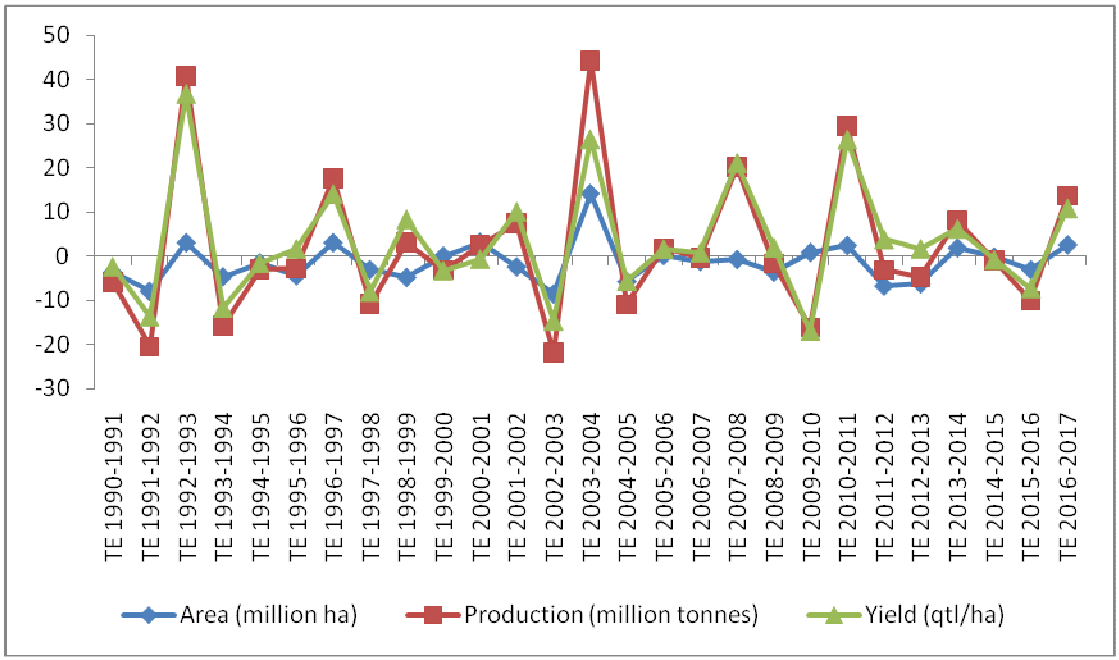


Fig 4.10: Triennium year on year growth of area, production and productivity of nutri cereals

during 2014 as well as unseasonal rains and hailstorms over February-March, 2015 (Sharma and Sendhil 2016). In case of nutri cereals, the annual productivity growth witnessed major downward surge of around 17 per cent in 2009-10 (Fig. 4.10).

Table 4.5: Mean and standard deviation of productivity under crops for different periods ***(qtl/ha)***

Crops	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Paddy	18.28 (0.72)	20.35 (1.02)	23.54 (0.98)	20.41 (2.26)
Wheat	24.41 (1.43)	27.10 (0.72)	30.19 (0.78)	26.90 (2.51)
Nutri cereals	9.55 (0.60)	11.70 (1.22)	15.84 (1.16)	11.98 (2.69)
Total cereals	16.97 (1.09)	19.70 (0.97)	23.52 (1.01)	19.68 (2.78)
Pulses	5.77 (0.14)	6.01 (0.26)	7.16 (0.37)	6.22 (0.63)
Food grains	14.75 (1.18)	17.16 (0.82)	20.27 (0.86)	17.07 (2.39)

Note: Figures in parentheses shows standard deviation

Table 4.6: Growth rate of productivity of crops for different time period

Crops	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Paddy	1.258* (10.57)	1.477* (5.83)	1.700** (3.28)	1.344* (22.95)
Wheat	1.909* (14.08)	0.397** (1.45)	0.135 (0.25)	1.128* (15.09)
Nutri cereals	1.989* (8.89)	3.228* (9.65)	3.170* (4.86)	2.663* (22.75)
Total cereals	2.138* (21.53)	1.403* (5.09)	1.658** (3.13)	1.744* (27.59)
Pulses	0.343 (1.32)	1.272* (5.71)	1.589 (1.93)	1.062* (8.93)
Food grains	2.613* (11.21)	1.330* (4.74)	1.554** (2.75)	1.734* (22.84)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

The average productivity of pulses during the comprehensive study period was minimum (6.22 qtl per hectare) compared to that of cereal crops, however mean productivity

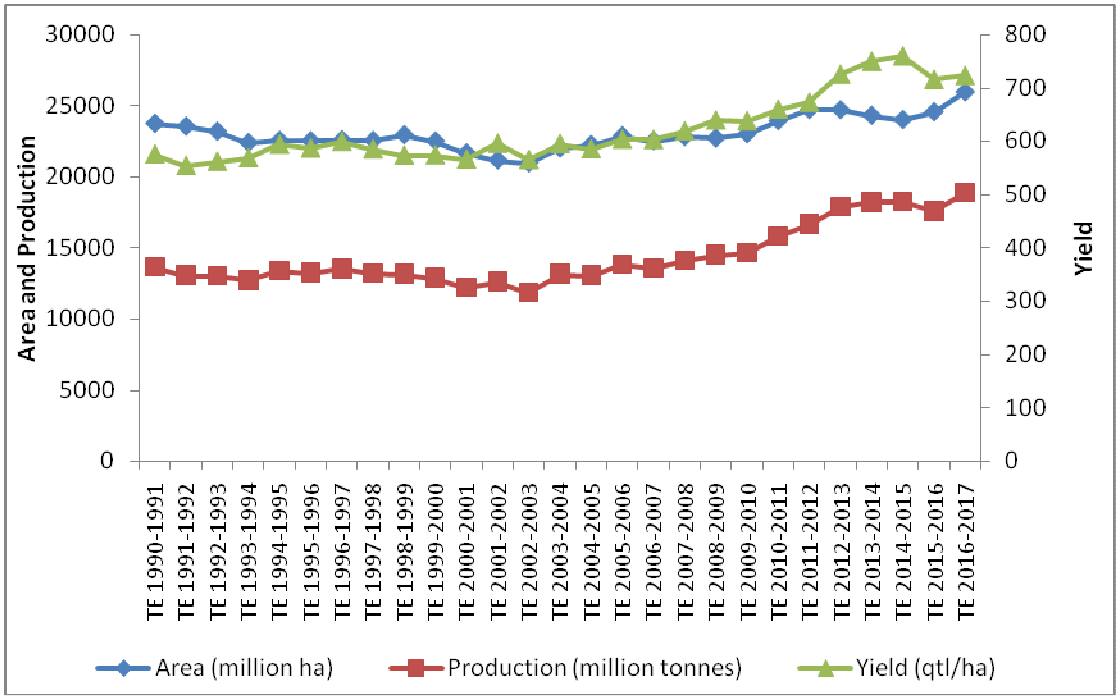


Fig 4.11: Area, production and productivity of pulses, TE 1990/91 to TE 2016/17

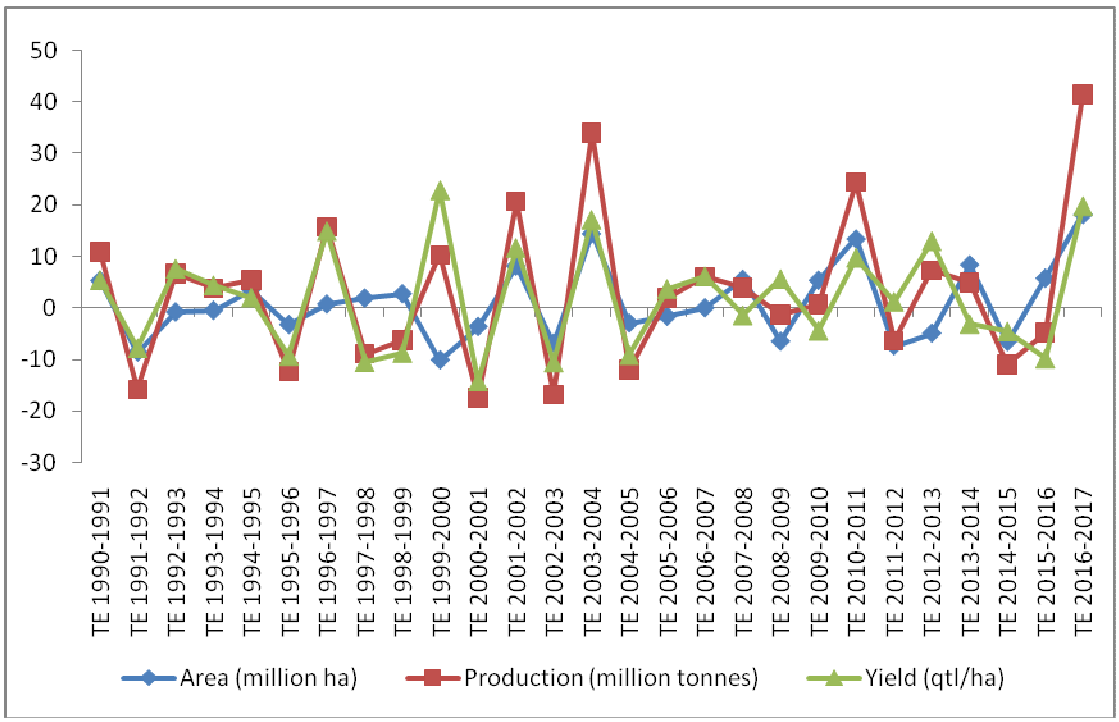


Fig 4.12: Triennium year on year growth of area, production and productivity of pulses

level has increased in all sub periods over the previous periods (Table 4.5). The productivity of pulses grew at significant annual rate of around 1 per cent over the entire study period, however in PI and PIII pulses witnessed non significant positive growth in productivity (Table 4.6). Despite the continuous upward trend of productivity of pulses (Fig. 4.11), the year on year growth analysis reveals regular upward and downward fluctuation (Fig. 4.12).

The above estimated trend of cereals, pulses and food grains is largely in confirmation with the trend estimated by earlier studies (Dasgupta and Sirohi 2010, Kannan 2012, Sharma 2012); however their study period differs from the present study.

4.1.4 Trend in procurement and distribution of rice and wheat

The importance of public distribution of food grains in ensuring food availability and enhancing food security in developing country like India needs no emphasis. The present form of India's public procurement and distribution of food grains dates back to1965 which was started to complement the Green Revolution in farming. Rice and wheat is primarily procured by central government through Food Corporation of India (FCI), in conjunction with state government agencies (Sinha 2012). The present section discusses the trend in procurement and distribution of rice and wheat over the entire study period and the three sub periods.

During the overall period, both the procurement and distribution of rice and wheat has increased with annual rate of above 5 per cent. The procurement growth of rice was although significant positive during PI and PII, the growth touched the record level of more than 6 per cent in the later period (Table 4.7).

Table 4.7: Growth rate of procurement and distribution of crops for different time period

Crop	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Procurement				
Rice	2.810* (4.51)	6.227* (12.93)	-0.281 (-0.64)	5.158* (21.48)
Wheat	3.418** (2.58)	-1.026 (-0.54)	1.848 (0.98)	5.214* (11.52)
Distribution				
Rice	4.285* (10.94)	8.653* (4.92)	1.728 (2.28)	6.052* (18.68)
Wheat	2.316 (1.96)	2.560 (0.79)	5.824** (3.51)	5.046* (10.27)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

In all the three sub periods, the procurement of wheat registered significant positive growth in only PI. The table 4.7 further reveals that distribution of rice grew significantly in PI and PII while that of in wheat it significant only in PIII.

4.2 Growth performance of food grains at regional level

The trend in growth rates of area, yield and productivity has been examined for different crops in Punjab and Uttar Pradesh separately over a period of TE 1990/91 to TE 2016/17 as well as sub periods TE 1990/91-2000/01 (PI), TE 2000/01-2010/11(PII) and TE2010/11-2016/17(PIII). Having discussed the compound annual growth rate we now move to carryout in depth analysis of this growth rate i.e. whether there has been acceleration, deceleration or stagnation in growth rate over different periods of time using the log-quadratic model. As discussed in the methodology section, when the coefficient of square term (t^2) is significantly positive it indicates acceleration, significant negative value shows deceleration in growth rate and insignificant value implies stagnation in growth process.

4.2.1 Area, production and yield dynamics of food grains

The mean area (Table 4.14), production (Table 4.15) as well as productivity (Table 4.16) of food grains have increased over successive decades in the state of Punjab. During the overall period, the growth in the production of food grains in Punjab is driven by both increases in area as well as productivity. Although the annual growth in area, production and productivity found to be positive and significant; their growth has decelerated significantly over the time (Table 4.8).

Decadal analysis reveals that in sub period PI as well as PII, there has been significant growth in production and is primarily productivity led growth in contrast to the growth in area. In sub period PIII, area has expanded significantly, however this increase in area doesn't make significant contribution in the growth of food grain production. Further, in all the sub periods the area has increased significantly but the increase has stagnated over successive decades whereas the growth in production and productivity has accelerated in sub period, followed by deceleration in sub period PIII (Table 4.8).

In the state of Uttar Pradesh, the average area (Table 4.14) under food grains has decreased over time but at the same time there has been increase in its production (Table 4.15) and yield (Table 4.16) as well. The significant growth in the production of food grains is solely by the increase in productivity since the growth in area has significantly declined by 0.19 per cent per annum during the overall study period. However, in the sub periods, the production has increased significantly only in PII and again this growth in production is mainly due to the growth in productivity. Over the decades (except in PIII), declining trend in area accompanied by acceleration in its negative growth has been observed. The growth in production and productivity has not followed any uniform trend as there is stagnation in their growth in PI followed by acceleration in PII and then deceleration in PIII (Table 4.8).

Table 4.8: Area, production and yield dynamics of food grains in Punjab and Uttar Pradesh

Periods	Area		Production		Yield	
	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration
Punjab						
TE 1990/91 to TE1999/00	0.700* (5.27)	0.073 (0.67)	1.965* (7.43)	-0.156 (-0.72)	1.262* (7.58)	-0.233 (-2.13)
TE 2000/01 to TE2009/10	0.355* (5.86)	0.075 (1.76)	0.996* (4.85)	0.390* (4.25)	0.644* (3.73)	0.315* (3.75)
TE 2010/11 to TE2016/17	0.294* (15.91)	-0.003 (-0.13)	0.500 (1.79)	-0.672* (-5.27)	0.207 (0.74)	-0.669* (-4.95)
TE1990/91 to TE2016/17	0.666* (20.64)	-0.028* (-3.64)	1.664* (21.68)	-0.074* (-4.38)	1.000* (19.91)	-0.046* (-4.02)
Uttar Pradesh						
TE 1990/91 to TE1999/00	-0.158 (-0.91)	0.342* (5.03)	2.238* (14.58)	0.225 (2.29)	2.384* (25.48)	-0.110 (-1.64)
TE 2000/01 to TE2009/10	-0.601* (-5.02)	0.198** (2.92)	-0.068 (-0.15)	0.795* (3.79)	0.539 (1.49)	0.604** (3.01)
TE 2010/11 to TE2016/17	0.184 (1.23)	-0.350** (-4.49)	-1.052 (-1.08)	-2.092** (-3.04)	-1.230 (-1.47)	-1.749** (-2.78)
TE1990/91 to TE2016/17	-0.198* (4.92)	0.026** (2.44)	1.027* (8.29)	-0.055 (-1.60)	1.222* (10.97)	-0.080* (2.82)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

4.2.2 Area, production and yield dynamics of total cereals

In Punjab, the average area under total cereals follows an increasing trend over decades with maximum area in sub period PIII and an average area of 61 million hectares during the whole study period (Table 4.14). The average production (Table 4.15) and productivity (Table 4.16) has also increased over time with the highest average production and yield of 280.39 million tonnes and 43 qtl per hectare in sub period PIII. During the overall period there has been significant growth in the production at an annual rate of 1.67 per cent and is attributed to both the growth in area (CAGR 0.75%) as well as yield (CAGR 0.92%). However, the increase in area, production and productivity from TE1990/91 to TE2016/17 registered significant deceleration in their growth trend. In all the sub periods, an increasing and significant trend in area under total cereals with stagnation in their growth rate has been observed. The production has noted to be increased significantly in sub period PI and PII and is marked by both area and productivity growth. Like food grains, in PIII only

area has increased significantly. Growth rate of production and productivity remain stagnated in PI, accelerated in PII and decelerated in PIII (Table 4.9).

The average area under total cereals in the state of Uttar Pradesh has increased marginally over the successive decades (Table 4.14) whereas during the same period average production of total cereals has increased by 26 per cent (Table 4.15) due to increase in its average yield from 20 to 26 qtl per hectare (Table. 4.16).

Table 4.9: Area, production and yield dynamics of total cereals in Punjab and Uttar Pradesh

Periods	**Area**		**Production**		**Yield**	
	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration
Punjab						
TE 1990/91 to TE1999/00	0.889* (6.08)	0.006 (0.05)	2.026* (7.65)	-0.144 (0.67)	1.136* (8.50)	-0.155 (-1.62)
TE 2000/01 to TE2009/10	0.431* (7.41)	0.067 (1.60)	1.008* (4.91)	0.389* (4.23)	0.579** (3.31)	0.322* (3.84)
TE 2010/11 to TE2016/17	0.220* (8.62)	0.036 (1.34)	0.290 (0.95)	-0.710** (-4.21)	0.070 (0.21)	-0.748** (-4.15)
TE1990/91 to TE2016/17	0.750* (19.13)	-0.041* (-5.19)	1.671* (20.23)	-0.083* (-4.86)	0.922* (18.82)	-0.042* (-3.72)
Uttar Pradesh						
TE 1990/91 to TE1999/00	0.285** (3.22)	0.186* (7.39)	2.604* (21.35)	0.132 (1.47)	2.316* (21.52)	-0.053 (0.60)
TE 2000/01 to TE2009/10	-0.420 (-2.29)	0.352* (4.49)	0.124 (0.26)	0.873* (3.90)	0.547 (1.69)	0.530** (2.88)
TE 2010/11 to TE2016/17	0.626* (4.59)	-0.293** (-3.03)	-0.382 (-0.45)	-1.911** (-3.64)	-0.984 (-1.31)	-1.621** (-3.07)
TE1990/91 to TE2016/17	0.009 (0.21)	0.026** (2.08)	1.241* (10.17)	-0.048 (-1.40)	1.232* (12.04)	-0.073* (-2.80)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

There has been significant growth in the production of total cereals in sub period PI and overall period at the rate of 2.6 and 1.24 per cent per annum, respectively; and is the resultant of area and yield as well. In sub period PII, yield led production growth has been reported since area has declined by 0.42 per cent per annum in the same sub period. It is noteworthy to mention here that the growth in the production has declined in the sub period PIII although non significantly. In the same period there has been significant expansion in the area however it could not compensate for the decline in productivity, therefore there has been

decrease in production. The long term acceleration has been registered in the growth trend of area except in sub period PIII where it has decelerated. The acceleration and deceleration in the growth trend in production and productivity does not show any regular pattern as clear from table 4.9.

4.2.3 Area, production and yield dynamics of paddy

The average area under paddy has increased gradually with an average area of around 25 million hectares during the overall period in the state of Punjab (Table 4.14). The average production shot up from 71 .95 million tonnes in 1990-2000 to 111.47 million tonnes in 2010-2017 (Table 4.15). During the same period productivity also shows increasing trend in the state (Table. 4.16). In the sub period PI, paddy production witnessed significant increase in its growth at the rate of 2.55 per cent per annum and is the resultant of significant increase in its area at an annual rate of 2.34 per cent. In sub period PII, significant contribution is made by both area and yield growth to the increase in production and again in sub period PIII area led growth has been noted.

Table 4.10: Area, production and yield dynamics of paddy in Punjab and Uttar Pradesh

Periods	**Area**		**Production**		**Yield**	
	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration
Punjab						
TE 1990/91 to TE1999/00	2.337* (9.68)	-0.017 (-0.09)	2.549* (6.55)	-0.357 (-1.19)	0.239 (1.08)	-0.339** (-2.49)
TE 2000/01 to TE2009/10	0.596* (4.97)	0.163 (2.04)	2.674* (15.57)	-0.093 (-0.66)	2.080* (14.98)	-0.255* (-3.82)
TE 2010/11 to TE2016/17	0.763* (11.40)	0.096 (1.34)	0.902* (4.58)	0.402 (2.59)	0.135 (0.70)	0.308 (1.58)
TE1990/91 to TE2016/17	1.526* (18.31)	-0.094* (-6.19)	2.438* (23.37)	-0.108* (-5.11)	0.913* (11.59)	-0.015 (-0.66)
Uttar Pradesh						
TE 1990/91 to TE1999/00	0.647* (3.95)	0.335* (6.13)	2.776* (8.96)	0.645* (6.76)	2.136* (10.89)	0.306** (2.58)
TE 2000/01 to TE2009/10	-0.107 (-0.44)	0.277 (1.58)	-0.163 (-0.32)	0.860** (3.19)	-0.035 (-0.09)	0.585** (2.45)
TE 2010/11 to TE2016/17	0.695* (4.78)	-0.187 (-1.15)	1.547 (1.62)	-2.234** (-4.37)	0.857 (1.00)	-2.056* (-5.16)
TE1990/91 to TE2016/17	0.352* (7.23)	-0.021 (-1.54)	1.310* (9.63)	-0.015 (-0.39)	0.957* (8.47)	0.006 (0.19)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

Finally in the overall comprehensive period there is increase in production at an annual rate of 2.44 per cent and is more of area led (CAGR 1.53%) than that of yield led growth (CAGR 0.91%). In all the sub periods the growth trend in both area and production has noted stagnation while deceleration in their growth rates in the overall period. However, growth rate of productivity has decelerated in sub period PI and PII and then observed stagnation in PIII as well as in whole study period (Table 4.10).

In state of Uttar Pradesh, there has been increase in the average area (Table 4.14), production (Table 4.15) as well as productivity (Table 4.16) of paddy over successive decades. During the comprehensive study period (TE1990/91 to TE2016/17) the production is found to be increasing at the rate of 1.31 per cent per annum significantly with the notable contribution of growth in area as well as productivity. However, the trend in area, production and productivity exhibit stagnation in their growth rate. In the sub period PI, there has been significant increase in production by the combined effect of both area as well as productivity growth and also the growth in all the three parameters has accelerated in the given period. In the sub period PII, negative growth rate of area, production and yield has been reported while in sub period PIII, area, production and yield of paddy has increased but non significantly. Further, the growth rate of area remains stagnated in period II and III, while that of production and yield first accelerated in PII and then decelerated in PIII (Table 4.10).

4.2.4 Area, production and yield dynamics of wheat

In the state of Punjab, the average area under wheat has increased marginally (Table 4.14) while average production has seen an impressive growth (Table 4.15) with increase in the productivity over successive decades (Table. 4.16). During the whole study period, the wheat production is increasing at the rate of 1.24 per cent per annum with significant growth in area (CAGR 0.38%) as well as productivity (0.87%). However, this positive and significant growth in area, production and yield has noted to be decelerated over time in the state. In sub period PI, productivity driven growth in production has been reported since area has increased non-significantly by marginal rate of 0.21 per cent per annum and the growth rate in above mentioned parameters remain stagnated over time. In sub period PII, there has been significant rise in the area but the production of wheat declined in the same period as the increase in area could not offset the decline in yield. The decline in production in sub period PIII was exclusively due to the significant fall in area growth during that period. However, there was stagnation in the growth rate of area in both the periods PI and PII; whereas acceleration in production and yield growth rate during PII and deceleration of the same in PIII (Table 4.11).

In Uttar Pradesh, the average production of wheat has increased substantially (Table 4.15) due to increase in average area (Table 4.14) and productivity over the succeeding decades (Table. 4.16). In the sub period PI, wheat production has seen an impressive growth

at the rate of 2.57 per cent per annum due to significant yield growth (CAGR 1.91%) as well as area growth (CAGR 0.80%) during the period. However in the same period stagnation in the growth of area, production and yield has been observed. The sub period PII has also recorded significant increase in production and it was primarily area driven; both area and productivity has increased and their growth rate has also accelerated over time but the area growth is more significant in comparison to productivity. Surprisingly in sub period PIII, the growth in production has declined at the rate of 2.87 per cent per annum and was mainly due to the decrease in the wheat yield at an annual rate of 2.92 per cent in the given period. Further, during the whole comprehensive period significant growth in production at an annual rate 1.55 per cent has been reported due to the combined effect of both area as well as productivity growth and long term deceleration has been noticed in production and productivity in the state of Uttar Pradesh (Table 4.11).

Table 4.11: Area, production and yield dynamics of wheat in Punjab and Uttar Pradesh

Periods	Area		Production		Yield	
	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration
Punjab						
TE 1990/91 to TE1999/00	0.209 (2.23)	-0.006 (-0.08)	1.838* (8.31)	-0.027 (-0.15)	1.625* (11.48)	-0.023 (-0.19)
TE 2000/01 to TE2009/10	0.422* (15.93)	0.0001 (0.06)	-0.039 (-0.12)	0.659* (4.92)	-0.4602 (-1.38)	0.657* (5.00)
TE 2010/11 to TE2016/17	-0.082* (-6.27)	-0.026 (-2.45)	-0.059 (-0.09)	-1.458* (-4.81)	0.022 (0.04)	-1.431* (-4.84)
TE1990/91 to TE2016/17	0.375* (15.39)	-0.016** (-2.51)	1.242* (12.42)	-0.073* (-2.92)	0.867* (9.25)	-0.057** (-2.31)
Uttar Pradesh						
TE 1990/91 to TE1999/00	0.802* (10.35)	-0.027 (-0.41)	2.567* (13.40)	-0.280 (-2.29)	1.906* (11.26)	-0.048 (-0.34)
TE 2000/01 to TE2009/10	0.344* (4.67)	0.125** (3.13)	1.218** (3.15)	0.458 (1.66)	0.562 (1.65)	0.578** (3.11)
TE 2010/11 to TE2016/17	0.112 (1.58)	-0.127 (-1.93)	-2.868 (-2.42)	-2.231 (-2.22)	-2.919 (-2.50)	-2.125 (-1.99)
TE1990/91 to TE2016/17	0.498* (21.21)	-0.013 (-2.00)	1.553* (10.09)	-0.113* (-2.91)	1.028* (7.26)	-0.107* (-3.03)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

4.2.5 Area, production and yield dynamics of nutri cereals

In Punjab nutri cereals occupied only 3 per cent of the area under total cereals and over consecutive decades it has declined substantially by 38 per cent (Table 4.14), however

the average production has increased by 9 per cent during the same time (Table 4.15) due to sharp rise in average productivity and is principally technology led growth (Table. 4.16). Over the period of time from TE1990/91 to TE2016/17, the production has achieved a significant growth rate and is attributed to rise in yield growth at an annual rate of 2.93 per cent since area has declined significantly by 2.50 per cent per annum, however this growth rate has registered long term stagnation over time in the state. Further the growth in area declined significantly in all the sub periods and stagnation in their growth rates was observed in all the sub periods. The growth rate of production witness negative rate except in sub period PII and this decline in productivity was found to be significant in PIII and was primarily attributed to the decline in area growth in the same period. It is noteworthy to mention here that the increase in productivity growth in sub period PI could not counteract the decline in area growth, therefore production has declined at a rate of 0.56 per cent per annum. Considering the acceleration and deceleration in trend, stagnation in sub period PI, acceleration in PII and deceleration in sub period PIII was noticed in production and yield growth rate (Table 4.12).

Table 4.12: Area, production and yield dynamics of nutri cereals in Punjab and Uttar Pradesh

Periods	**Area**		**Production**		**Yield**	
	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration
Punjab						
TE 1990/91 to TE1999/00	-3.029* (-10.19)	-0.152 (-0.62)	-0.562 (-1.14)	-0.291 (-0.73)	2.399* (4.19)	-0.058 (-0.12)
TE 2000/01 to TE2009/10	-1.717* (-12.09)	-0.105 (0.93)	0.857 (1.51)	1.029* (3.65)	2.598* (4.54)	1.133* (5.05)
TE 2010/11 to TE2016/17	-3.186* (-8.78)	0.139 (0.30)	-2.009* (-4.06)	-1.159** (-4.32)	1.119 (2.06)	-1.267** (-4.29)
TE1990/91 to TE2016/17	-2.502* (-28.88)	-0.047 (-1.99)	0.435* (3.18)	-0.039 (-1.00)	2.925* (23.90)	0.013 (0.35)
Uttar Pradesh						
TE 1990/91 to TE1999/00	-1.865* (-7.53)	0.398** (2.74)	-0.219 (-0.67)	0.197 (0.74)	1.648* (7.91)	-0.212 (-1.35)
TE 2000/01 to TE2009/10	-2.521* (-9.17)	0.353 (1.86)	-1.761* (-4.29)	0.594 (2.25)	0.758** (2.65)	0.269 (1.23)
TE 2010/11 to TE2016/17	-0.017 (-0.15)	-0.230 (-2.71)	2.719** (3.50)	-1.867* (-5.10)	2.732** (3.93)	-1.649* (-4.65)
TE1990/91 to TE2016/17	-2.261* (-18.97)	0.114* (4.33)	-0.689* (-3.31)	0.197* (4.28)	1.576* (15.02)	0.082* (3.18)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

Contrarily, in the state of Uttar Pradesh even though the average productivity (Table 4.16) over the entire period increased with accelerated rate, it could not make up to the accelerated decline in average area (CAGR 2.26%) (Table 4.14) and thus the average production of nutri cereals (Table 4.15) also decreased (CAGR 0.69%) with accelerated rate during the same time period. Decadal analysis shows that in sub period PI, area decline surpassed the increase in yield hence there was decrease in overall production. In this period only area recorded acceleration in its growth rate while production and yield has stagnated over time. In sub period PII, growth in production declined at an annual rate of 1.76 per cent and again was accorded to area decline by 2.52 per cent per annum. The growth rate of area, production and yield witnessed stagnation in the sub period II. Significant increase in the production has been noticed only in sub period PIII at an impressive rate of 2.72 per cent per annum and was absolutely yield driven growth. Also long term significant deceleration was noted in production and yield in this period (Table 4.12).

4.2.6 Area, production and yield dynamics of pulses

In the state of Punjab the average area under pulses during the study period was only 0.65 million hectares and it has decreased over the decades (Table 4.14) and accordingly average production also declined by around 60 per cent between PI to PIII (Table 4.15). However, average productivity of pulses increased from 7.64 qtl per hectare in PI to 8.68 qtl per hectare in PIII, i.e., approximately by 14 per cent (Table 4.16). The growth of pulse production in the state presents a gloomy trend during the whole study period as significant decline at the rate of 5.40 per cent per annum was observed and the decline was mainly because of significant decline in area (CAGR 6.08%) during the same period. During this period acceleration in the respective growth rates of area, production and yield of pulses was noticed. Decadal analysis of growth rates reveals that pulse production registered impressive annual growth of 15.18 per cent in sub period PIII and the growth was mainly area driven growth, however the trend in area and production remain stagnated during the same period. It is noteworthy that in sub period PII productivity increased significantly, however it could not offset the sharp decline in area and thus production also declined. Similar declining trend of area and production was observed in sub period PI as well.

In the state of Uttar Pradesh, the average production of pulses declined from 24.83 in sub period PI to 19.97 million tonnes sub period PIII (Table 4.15) due to decrease in average area under pulses by around 18 per cent (Table 4.14) as well as decline in yield (Table 4.16) during the same period. During the entire study period the growth in the production of pulses showed dismal trend and it declined at an annual rate of 1.39 per cent significantly. The decline in the production was mainly attributed to the significant decline in area (CAGR 1.107%) during the same period, though the area declined with decelerated rate.

Table 4.13: Area, production and yield dynamics of pulses in Punjab and Uttar Pradesh

Periods	Area		Production		Yield	
	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration
Punjab						
TE 1990/91 to TE1999/00	-5.862* (-7.78)	0.572 (0.96)	-6.230* (-5.49)	-0.850 (-0.94)	-0.432 (-0.57)	-1.430* (-4.33)
TE 2000/01 to TE2009/10	-11.068* (-52.03)	-0.171 (-1.02)	-8.511* (-21.61)	-0.541 (-2.06)	2.561* (11.40)	-0.322 (-2.22)
TE 2010/11 to TE2016/17	15.013** (3.56)	-7.876 (-2.10)	15.178* (4.06)	-6.129 (-1.64)	0.194 (0.26)	1.759* (5.01)
TE1990/91 to TE2016/17	-6.084* (-7.75)	0.708* (3.95)	-5.404* (-6.85)	0.796* (4.82)	0.686* (4.41)	0.089* (2.11)
Uttar Pradesh						
TE 1990/91 to TE1999/00	-0.893* (-19.87)	0.029 (0.81)	-1.117* (-6.08)	0.184 (1.33)	-0.220 (-1.26)	0.162 (1.20)
TE 2000/01 to TE2009/10	-1.583* (-3.54)	-0.823* (-3.86)	-3.045* (-10.62)	-0.409 (-2.20)	-1.444* (-4.82)	0.434 (2.25)
TE 2010/11 to TE2016/17	-1.727** (-3.70)	-0.479 (-0.87)	-4.467 (-1.90)	-5.358** (-3.76)	-3.015 (-1.41)	-5.009** (4.32)
TE1990/91 to TE2016/17	-1.107* (-15.48)	-0.042** (-2.22)	-1.398* (-7.42)	-0.022 (-0.39)	-0.305 (-1.78)	0.014 (0.29)

*Significant @ 1%, ** significant @ 5 % level of significance
Note: Figures in parentheses shows two-tailed t-statistics value

The decadal analysis also showed significant decline in the pulses production in sub period PI and PII, however in PIII non significant decline in production has been observed. The significant decline in area (CAGR 1.58%) as well as productivity (CAGR 1.44%) was the prime reason behind the decline in pulse production in PII.

Table 4.14: Mean and standard deviation of area under crops for different periods

(million hectares)

Crops	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Punjab				
Rice	21.63 (1.60)	26.10 (0.54)	28.53 (0.48)	25.07 (3.03)
Wheat	32.76 (0.34)	34.45 (0.45)	35.13 (0.07)	34.00 (1.06)
Nutri cereals	2.30 (0.22)	1.86 (0.10)	1.43 (0.10)	1.91 (0.38)
Total cereals	56.69 (1.69)	62.40 (0.88)	65.09 (0.32)	60.99 (3.70)
Pulses	1.06 (0.21)	0.43 (0.14)	0.38 (0.13)	0.65 (0.36)
Food grains	57.82 (1.40)	62.83 (0.75)	65.47 (0.42)	61.66 (3.32)
Uttar Pradesh				
Rice	55.58 (1.36)	58.25 (1.22)	59.20 (0.98)	57.51 (1.95)
Wheat	89.30 (2.25)	93.57 (1.15)	97.93 (0.41)	93.12 (3.77)
Nutri cereals	30.35 (1.87)	22.59 (1.85)	20.03 (0.11)	24.80 (4.72)
Total cereals	175.16 (2.02)	172.08 (3.50)	176.08 (2.64)	174.26 (3.21)
Pulses	28.70 (0.78)	26.12 (1.54)	23.45 (1.01)	26.38 (2.38)
Food grains	205.17 (3.22)	198.50 (4.19)	198.87 (1.63)	201.07 (4.54)

Note: Figures in parentheses shows standard deviation

Table 4.15: Mean and standard deviation of production under crops for different periods *(million tonnes)*

Crops	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Punjab				
Rice	71.95 (5.93)	97.30 (7.96)	111.47 (2.43)	91.58 (17.40)
Wheat	129.23 (7.63)	150.20 (4.31)	163.67 (4.86)	145.92 (15.20)
Nutri cereals	4.81 (0.22)	5.23 (0.29)	5.25 (0.25)	5.08 (0.33)
Total cereals	205.99 (13.43)	252.73 (9.01)	280.39 (4.49)	242.59 (32.17)
Pulses	0.82 (0.17)	0.33 (0.08)	0.33 (0.11)	0.51 (0.27)
Food grains	207.17 (13.14)	253.05 (8.94)	281.80 (4.84)	243.51 (32.10)
Uttar Pradesh				
Rice	105.65 (9.54)	117.19 (5.06)	134.94 (7.61)	117.52 (13.77)
Wheat	213.88 (16.80)	252.70 (12.72)	287.10 (24.00)	247.24 (33.97)
Nutri cereals	38.88 (1.12)	32.19 (2.12)	34.96 (2.37)	35.39 (3.46)
Total cereals	357.92 (28.59)	398.08 (16.17)	452.57 (19.00)	397.33 (43.31)
Pulses	24.83 (0.93)	21.25 (1.99)	19.97 (2.88)	22.24 (2.81)
Food grains	383.56 (26.66)	420.25 (15.61)	467.53 (24.47)	418.92 (39.83)

Note: Figures in parentheses shows standard deviation

Table 4.16: Mean and standard deviation of productivity under crops for different periods *(qtl/ha)*

Crops	TE 1990/91 to TE 1999/00	TE 2000/01 to TE 2009/10	TE 2010/11 to TE 2016/17	TE 1990/91 to TE 2016/17
Punjab				
Rice	33.24 (0.67)	37.24 (2.36)	39.08 (0.38)	36.24 (2.85)
Wheat	39.43 (2.00)	43.60 (1.39)	46.58 (1.36)	42.83 (3.31)
Nutri cereals	21.08 (1.81)	28.20 (2.69)	36.75 (1.28)	27.78 (6.56)
Total cereals	36.29 (1.31)	40.48 (0.94)	43.08 (0.68)	39.60 (2.96)
Pulses	7.64 (0.50)	7.86 (0.62)	8.68 (0.31)	7.99 (0.65)
Food grains	35.79 (1.44)	40.26 (0.99)	43.04 (0.61)	39.33 (3.17)
Uttar Pradesh				
Rice	18.99 (1.28)	20.10 (0.66)	22.78 (1.03)	20.38 (1.81)
Wheat	24.06 (1.43)	27.14 (0.93)	29.35 (2.46)	26.57 (2.65)
Nutri cereals	12.83 (0.68)	14.28 (0.48)	17.45 (1.15)	14.57 (1.99)
Total cereals	20.42 (1.44)	23.12 (0.75)	25.71 (1.08)	22.79 (2.38)
Pulses	8.65 (0.14)	8.13 (0.42)	8.48 (1.02)	8.41 (0.60)
Food grains	18.71 (1.35)	21.17 (0.75)	23.50 (1.14)	20.86 (2.20)

Note: Figures in parentheses shows standard deviation

The studies pertaining to growth performances of food grains at regional level are scant. However, the significant growth in area under paddy in Punjab has been unanimously reported (Rang *et al* 2011, Grover *et al* 2016, Gulati *et al* 2017). The studies carried out by Grover and Singh (2012), also reported significant decline in area and production of pulses over time. Further, the findings of the present study on growth performance of food grains in Uttar Pradesh is also in confirmation with Bhagat (2000), Bajpai and Volavka (2005), Goyal and Kumar (2013), Singh and Supriya (2017) where yield led growth in production of food grains has been reported after the reform period. It is noteworthy to mention here that, none of the previous standard studies at regional level had focussed on acceleration and deceleration

aspect of growth rate, therefore the present study is pioneer in this context.

4.2.7 Contribution of states

In order to have clear understanding of contribution of Punjab and Uttar Pradesh in area and production of food grains of the country over the study period, the share of both the states was analysed at more disaggregated crop and sub period level. The larger share of Uttar Pradesh in area and production of food grains and all the individual crops than that of the Punjab doesn't need much emphasis due to the larger geographical area of the former. However, it is interesting to note that while the mean share of Punjab in area under total food grains is around four times lower than that of Uttar Pradesh; its production share is only 8 percentage points lower than that of the later (Table 4.17). It would not be out of the place to mention that while area share of Punjab has increased significantly during TE 1990/91-TE2016/17, growth in the area share has significantly declined over the same period (Fig 4.13).

Table 4.17: Temporal contribution (%) of Punjab and Uttar Pradesh in area and production of food grains

	Punjab											
Time period	Paddy		Wheat		Nutri cereals		Total cereals		Pulses		Food grains	
	A	P	A	P	A	P	A	P	A	P	A	P
PI	5.04 (0.29)	9.15 (0.35)	13.05 (0.54)	21.09 (1.10)	0.70 (0.02)	1.54 (0.08)	5.61 (0.20)	12.01 (0.27)	0.46 (0.08)	0.62 (0.12)	4.59 (0.28)	11.14 (0.34)
PII	5.99 (0.18)	11.00 (0.66)	12.85 (0.28)	20.70 (0.79)	0.64 (0.03)	1.55 (0.10)	6.29 (0.11)	12.95 (0.35)	0.20 (0.07)	0.25 (0.08)	5.17 (0.06)	12.15 (0.34)
PIII	6.56 (0.07)	10.91 (0.42)	11.75 (0.39)	18.13 (0.63)	0.55 (0.02)	1.28 (0.09)	6.54 (0.03)	12.01 (0.39)	0.15 (0.05)	0.18 (0.05)	5.28 (0.03)	11.22 (0.34)
Overall Period	5.78 (0.66)	10.29 (1.02)	12.64 (0.68)	20.18 (1.51)	0.64 (0.06)	1.48 (0.15)	6.10 (0.42)	12.36 (0.56)	0.28 (0.16)	0.37 (0.21)	4.98 (0.35)	11.54 (0.58)
	Uttar Pradesh											
PI	12.95 (0.11)	13.44 (0.55)	35.54 (0.84)	35.03 (0.89)	9.20 (0.18)	12.42 (0.39)	17.33 (0.24)	20.86 (0.46)	12.57 (0.22)	18.86 (0.80)	16.26 (0.52)	20.62 (0.48)
PII	13.36 (0.19)	13.22 (0.67)	34.91 (0.71)	34.96 (0.67)	7.79 (0.51)	9.64 (1.31)	17.33 (0.25)	20.38 (0.91)	11.81 (0.96)	16.15 (2.56)	16.32 (0.38)	20.17 (1.05)
PIII	13.60 (0.14)	13.17 (0.37)	32.73 (0.94)	31.76 (3.17)	7.72 (0.37)	8.53 (0.32)	17.70 (0.28)	19.36 (0.91)	9.57 (0.55)	11.37 (1.90)	16.03 (0.18)	18.60 (1.19)
Overall Period	13.27 (0.31)	13.29 (0.55)	34.58 (1.39)	34.16 (2.19)	8.29 (0.79)	10.38 (1.85)	17.42 (0.29)	20.29 (0.95)	11.51 (1.37)	15.92 (3.50)	16.22 (0.41)	19.93 (1.21)

Note: Figures in parentheses shows standard deviation
PI-TE1990/91-2000/01, PII-TE2000/01-2010/11, PIII-TE2010/11-2016/17, Overall Period-TE1990/91-2016/17

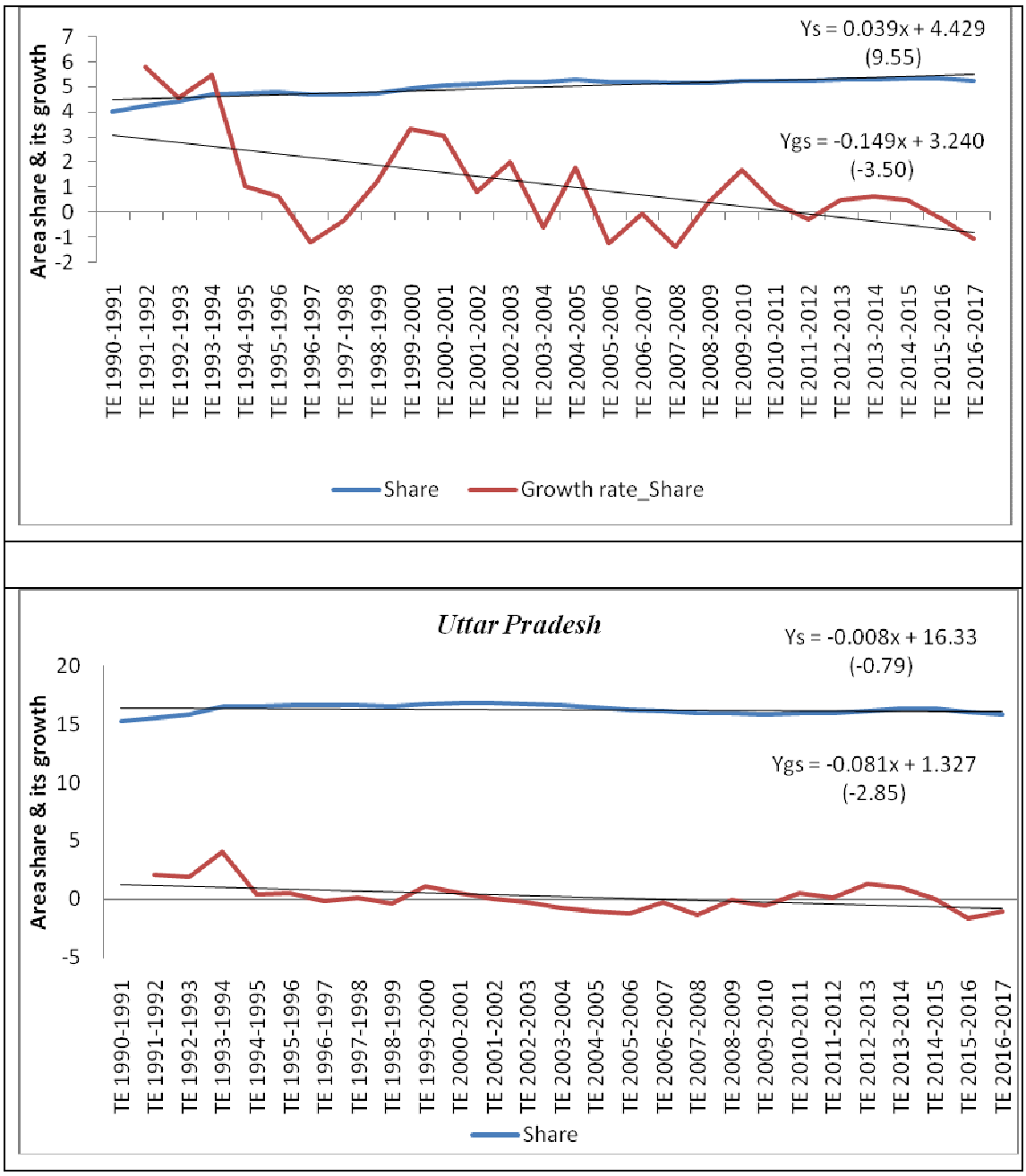
Further, whereas production share of Punjab has increased, though non significantly, over the study period; the same has significantly declined for Uttar Pradesh over the same period (Fig 4.14). Also, growth rate of production share has significant declining trend for both the states.

The share of both the states in area under total cereals has significantly increased over the time, however, the growth in area share in Punjab witnessed significant declining trend during the same time period (Fig 4.15). The production share of Punjab in total cereals has increased though non significantly during TE 1990/91-TE2016/17; the growth in the production share of the state has significantly turned down over the same period. In case of Uttar Pradesh, both the production share and its growth registered declining trend over the same period (Fig 4.16).

In case of paddy, the area share of Punjab witnessed significant increase while the growth rate of area share declined in the state, though non significantly during the entire study period. However, in Uttar Pradesh significant rise in area share has been noted over the comprehensive study period and the growth in area share increased non significantly in the state during the same period (Fig. 4.17). The production share of paddy in Punjab registered significant increase over time while the growth share of production noted non significant decline in the state during the same time. In Uttar Pradesh both production share and its growth rate decreased non significantly during the given study period (Fig. 4.18).

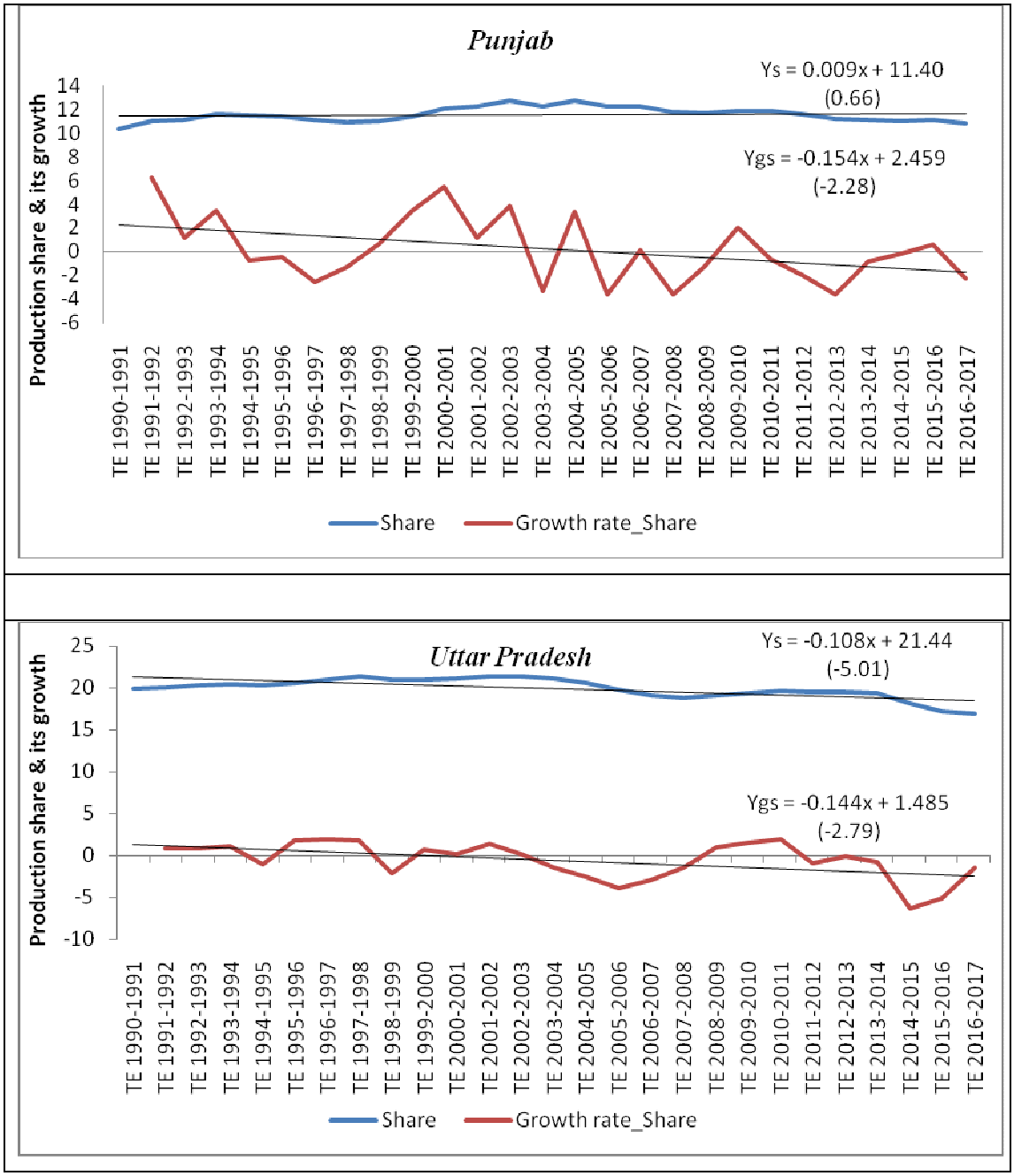
The area share of wheat in both the states viz., Punjab and Uttar Pradesh registered significant decline while the growth rate of area share witnessed non significant decreasing trend during the overall period (Fig. 4.19). Similarly, the production share of both the states for wheat also turned down significantly during the entire study period. The growth rate of production share of Uttar Pradesh for wheat also declined significantly over the time (Fig. 4.20). The area and production share of both the states in nutri cereals decreased significantly (Fig 4.21; Fig 4.22). While the trend of growth rate of area and production share of Uttar Pradesh for nutri cereals is non significant, the growth rate of production share of Punjab registered significantly declining trend over the same period.

In case of pulses, area share (Fig, 4.23) as well as production share (Fig. 4.24) of Punjab has decreased significantly over the time; however, the growth rate of the share for both the parameters witnessed non significant declining trend. Interestingly, the share of Uttar Pradesh in area and production for pulses along with the growth rate of share registered significant declining trend over the study period.



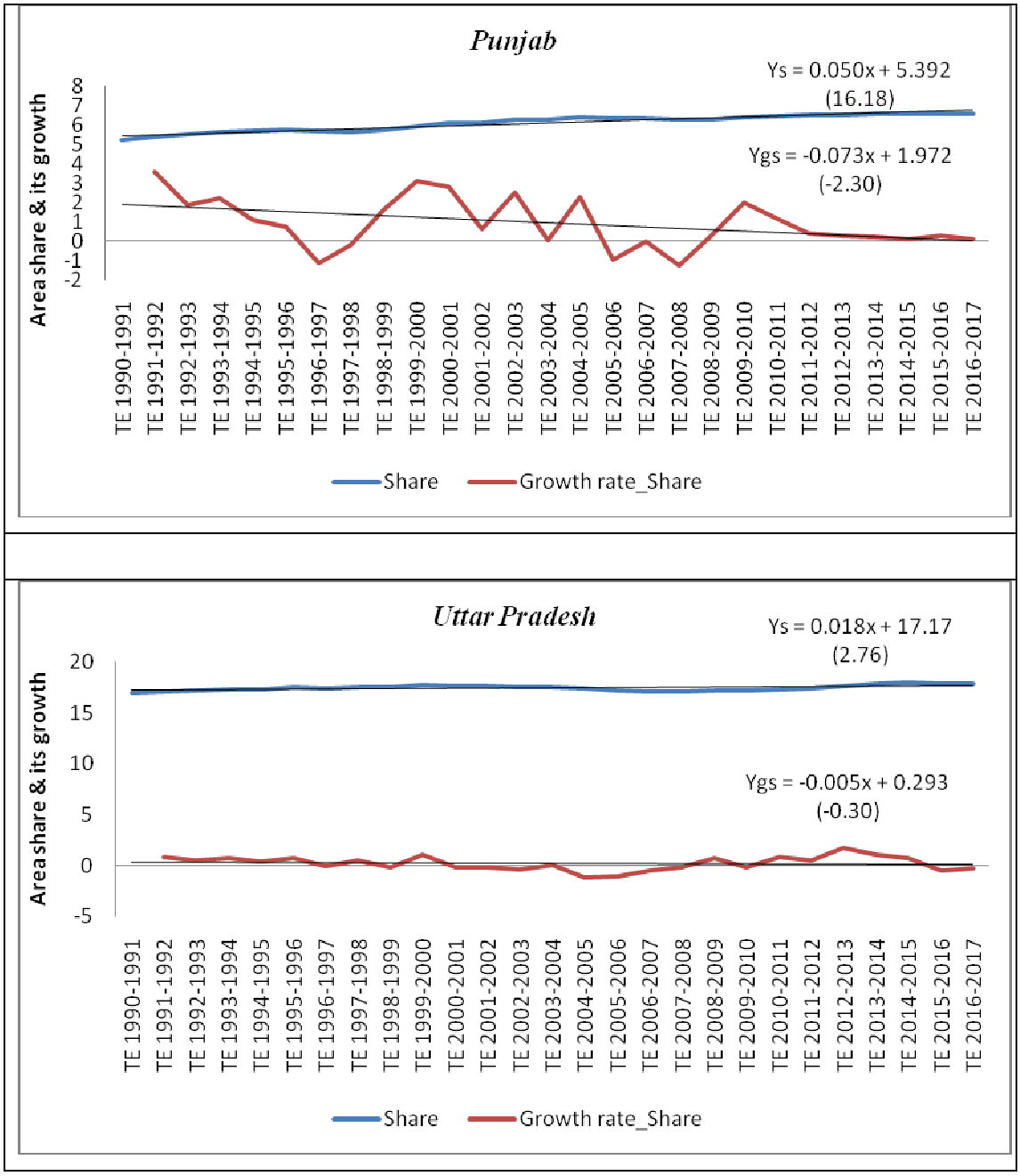
Note: Ys represents area share; Ygs represents growth rate of area share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.13: Share in area of food grains and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



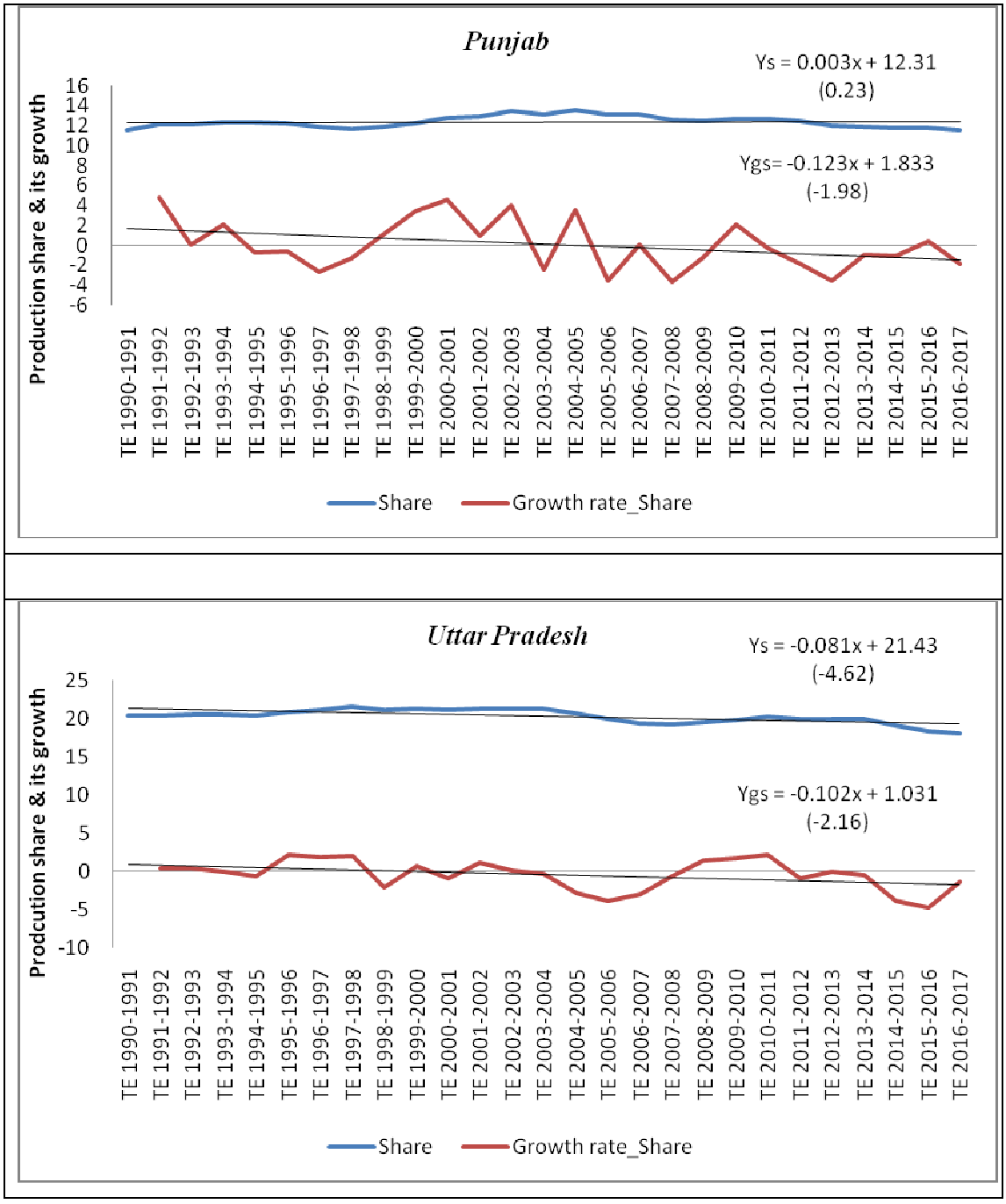
Note: Ys represents production share; Ygs represents growth rate of production share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.14: Share in production of food grains and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



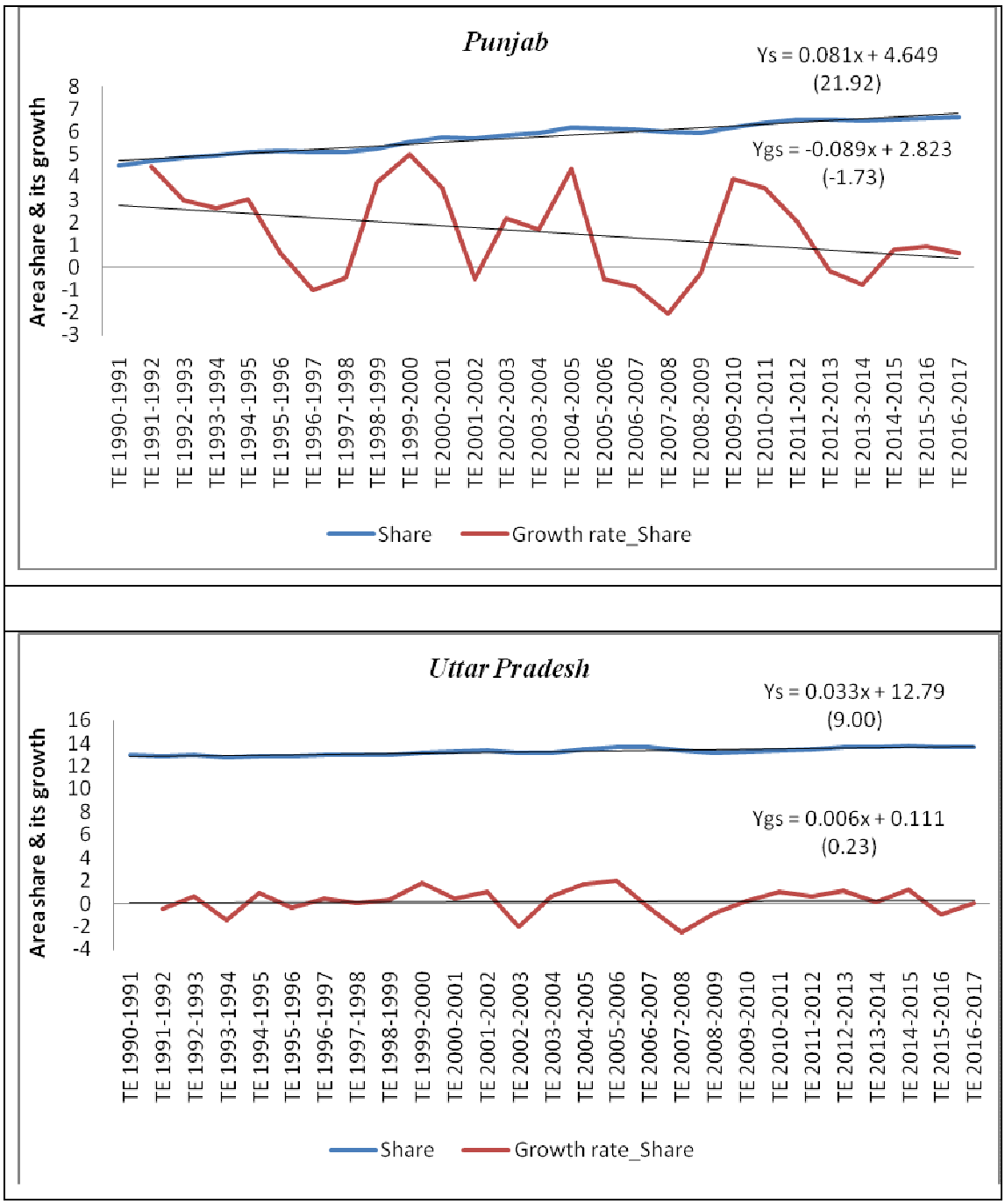
Note: Ys represents area share; Ygs represents growth rate of area share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.15: Share in area of total cereals and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



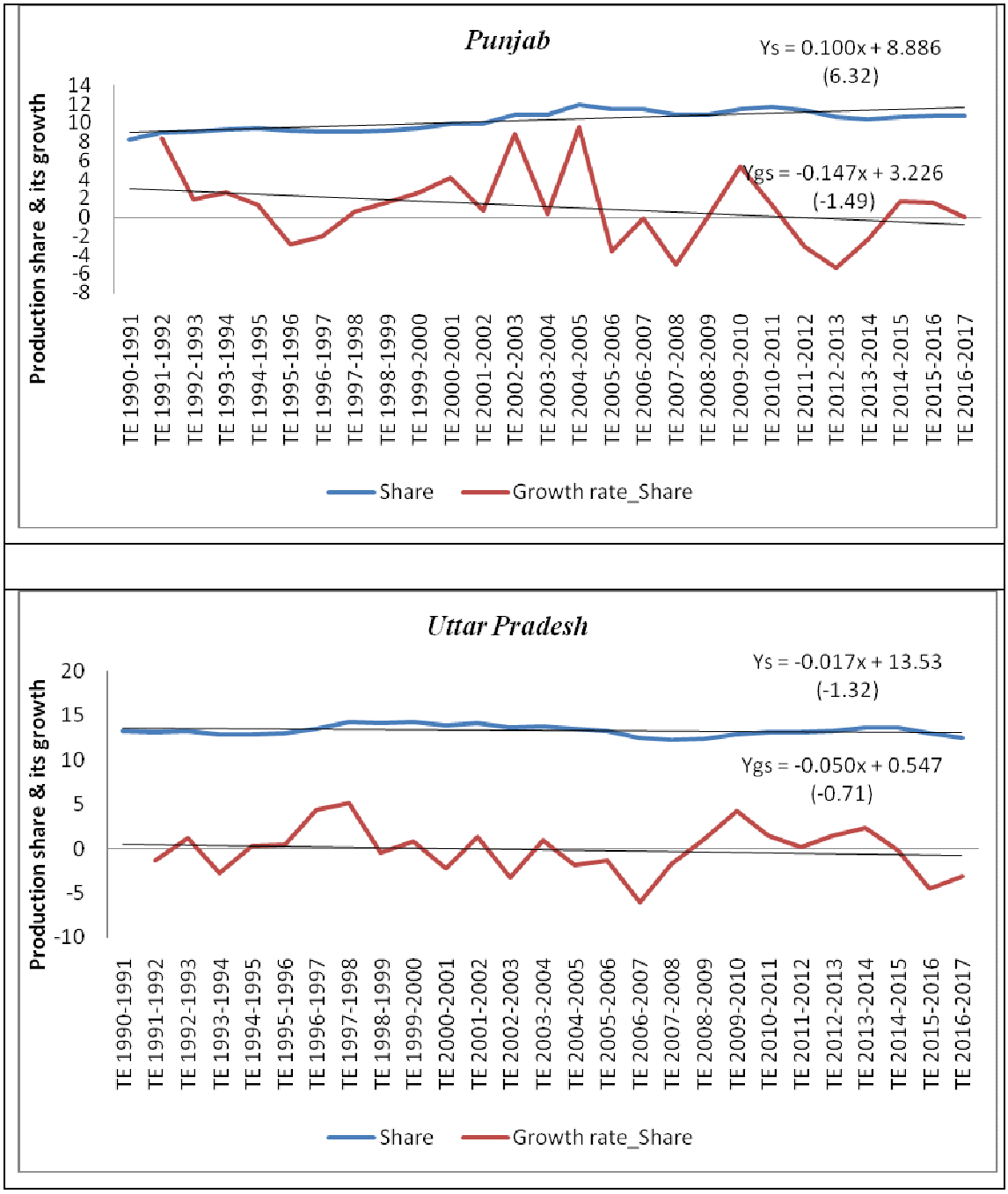
Note: Ys represents production share; Ygs represents growth rate of production share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.16: Share in production of total cereals and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



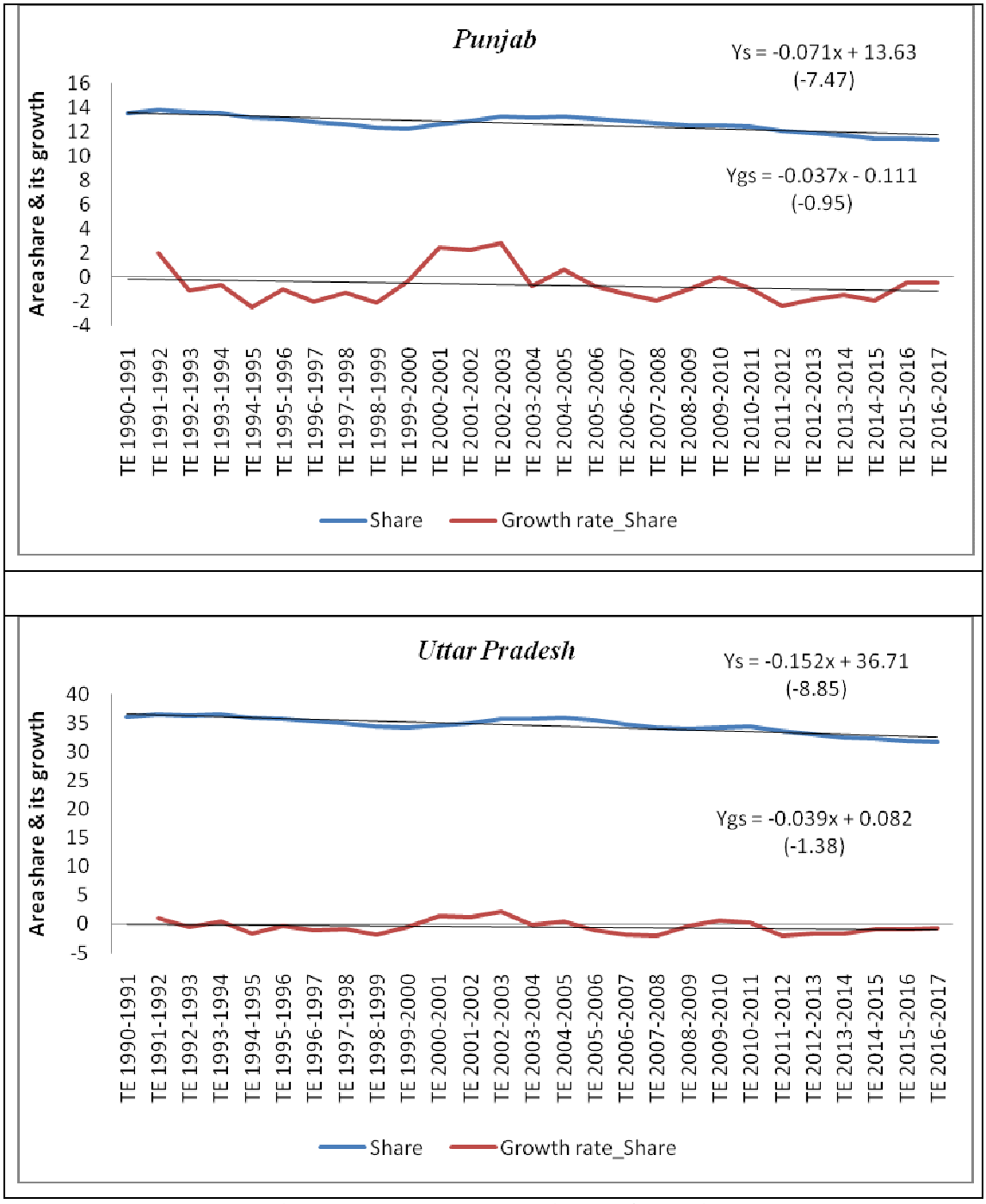
Note: Ys represents area share; Ygs represents growth rate of area share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.17: Share in area of paddy and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



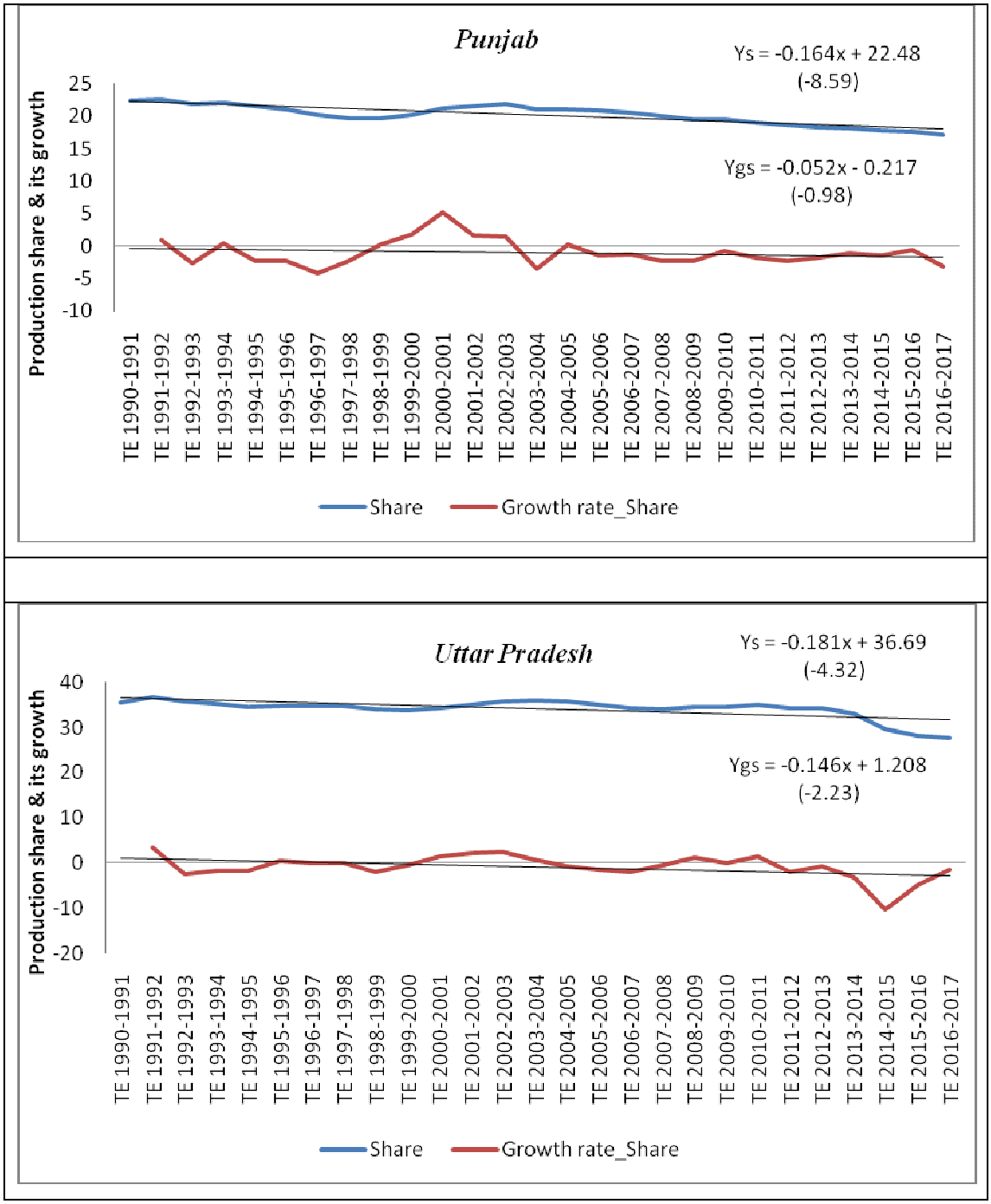
Note: Ys represents production share; Ygs represents growth rate of production share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.18: Share in production of paddy and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



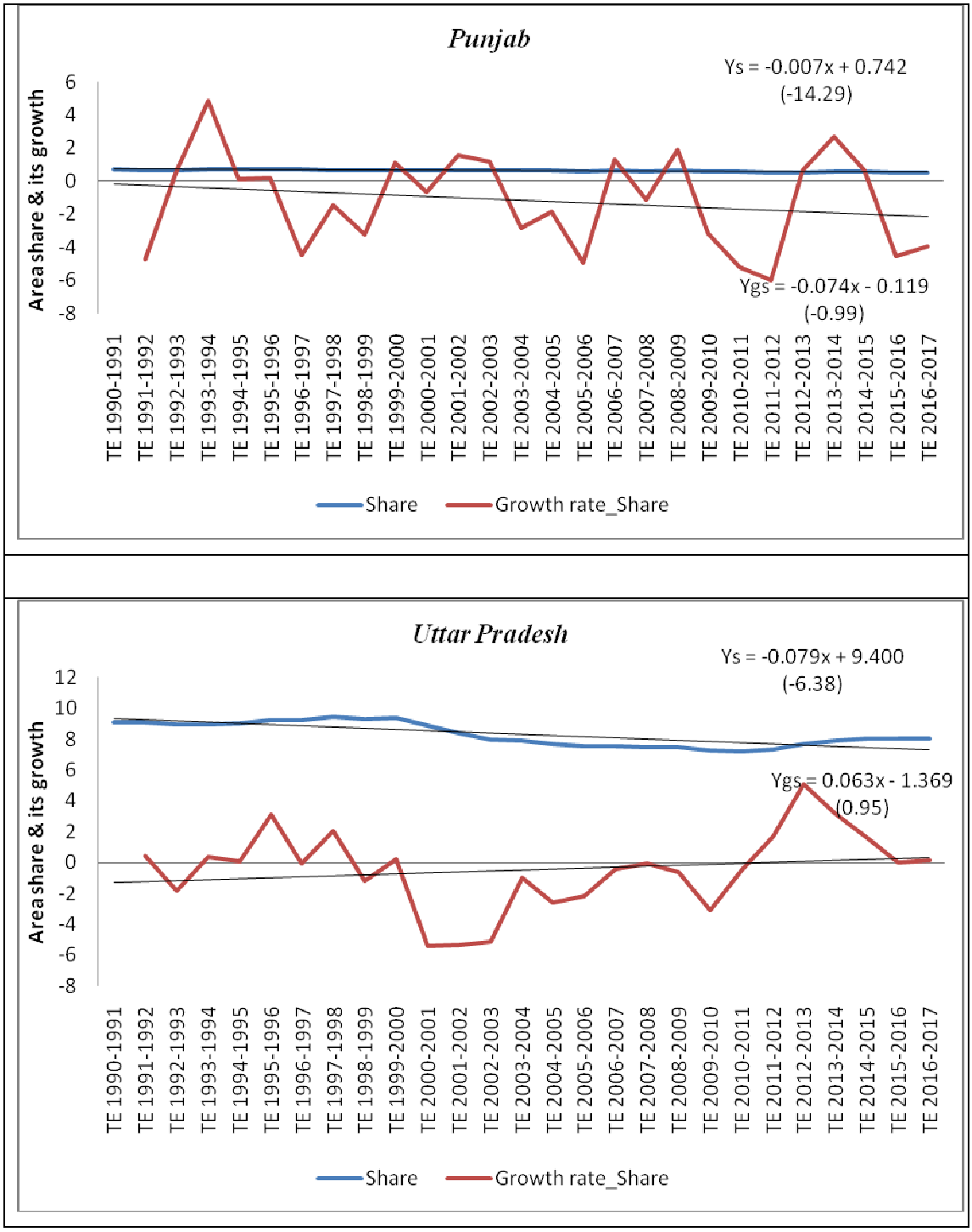
Note: Ys represents area share; Ygs represents growth rate of area share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.19: Share in area of wheat and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



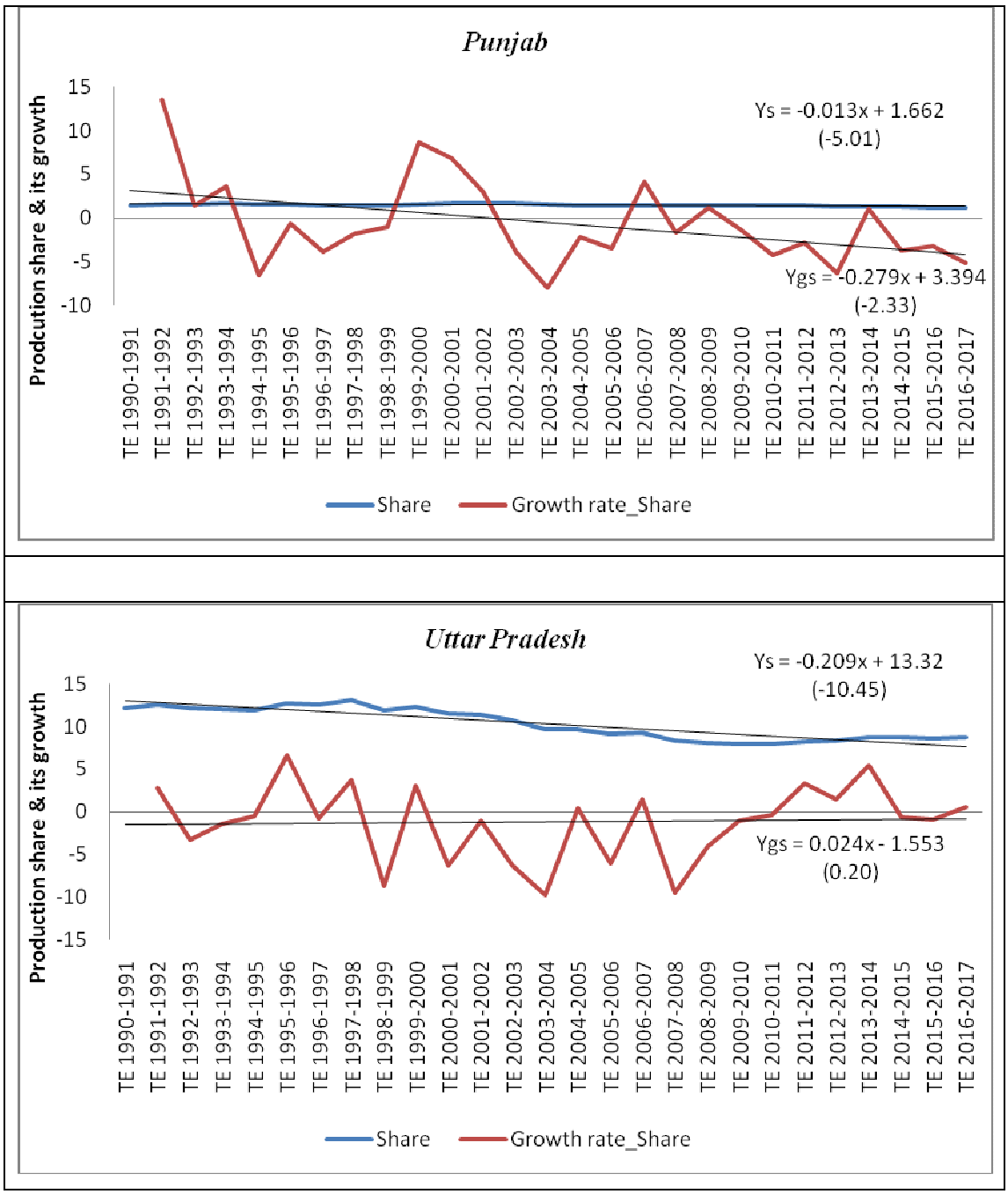
Note: Ys represents production share; Ygs represents growth rate of production share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.20: Share in production of wheat and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



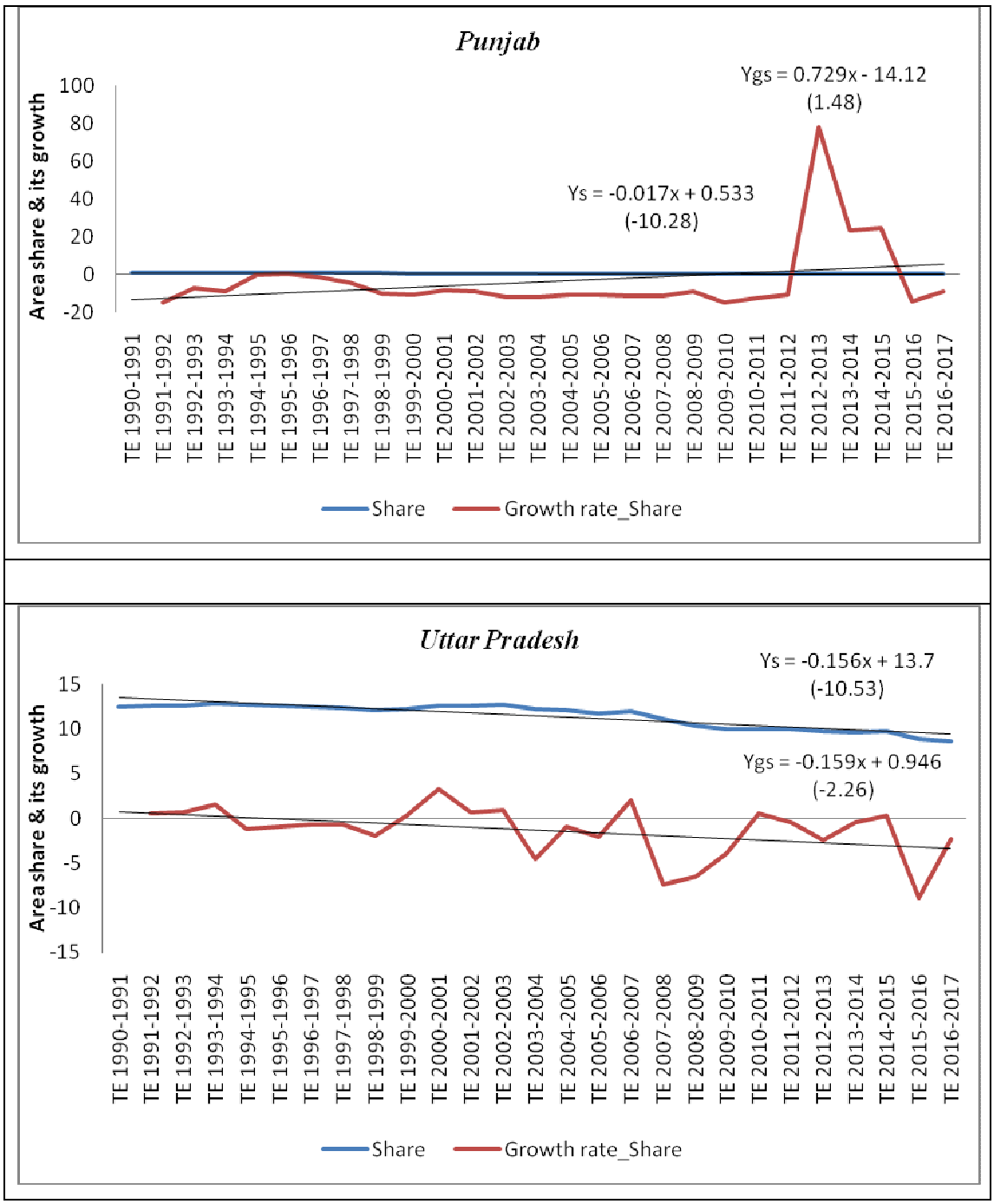
Note: Ys represents area share; Ygs represents growth rate of area share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.21: Share in area of nutri cereals and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



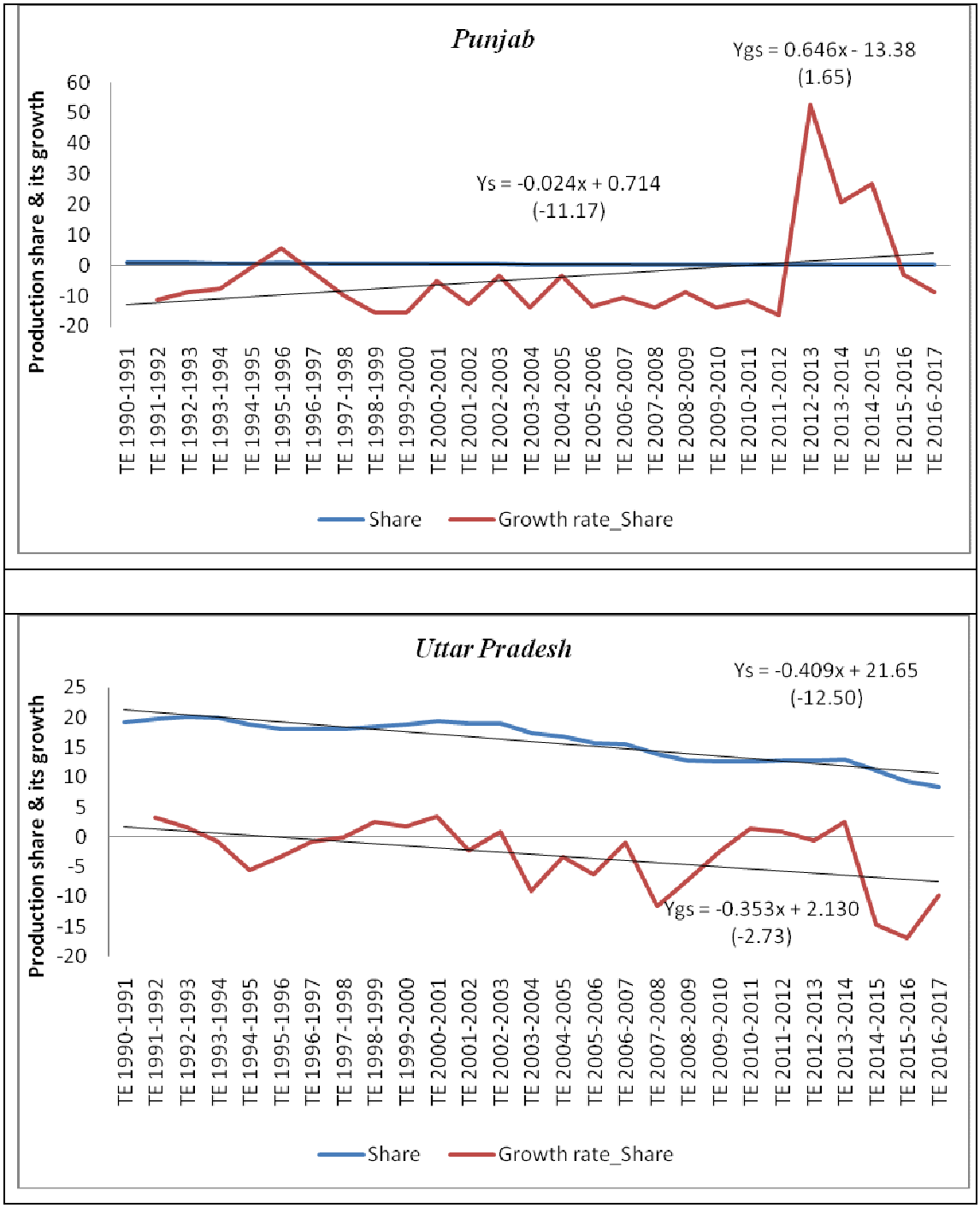
Note: Ys represents production share; Ygs represents growth rate of production share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.22: Share in production of nutri cereals and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



Note: Ys represents area share; Ygs represents growth rate of area share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.23: Share in area of pulses and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17



Note: Ys represents production share; Ygs represents growth rate of production share
Figures in parentheses shows two-tailed t-statistics value

Fig 4.24: Share in production of pulses and its Year-on-Year growth rate over TE 1990/91 to TE 2016/17

4.3 Sustainability of food security

The above discussion indicated the growth performance of agricultural crops over a period of time at national as well as in the study area. In this section detail discussion on sustainability of food security at district level in the states of Punjab and Uttar Pradesh has been presented. The analysis of food security and its sustainability status assists in identifying the districts/regions which are more secure as well as sustained in terms of food security along with the factors accounting for this security and sustainability. This would be instrumental in prioritizing policy attention and orientation of the development programme. Therefore district wise sustainable food security index along with its three component indices viz., sustainable food availability index (comprised of index of food availability security and index of food availability sustenance), sustainable food access index (index of food access security and index of food access sustenance) and food utilization index was constructed. The discussion on the indices of the components of sustainable food security precedes the results of sustainable food security index of the study area.

4.3.1 Sustainable food availability index

The index was constructed by combining its two sub–indices i.e., Index of food availability security (FAI) and Index of food availability sustenance (FSI). Therefore, the following subsections present detail discussion on sub-indices for the study area.

4.3.1.1 Index of food availability security: The sub-index was computed using total of seven indicators which were cropping intensity, change in net sown area, food grain production per capita, irrigation intensity, fertilizer consumption, population density and milk productivity. The weights were assigned to each indicator using the first principal component which explained around 90 per cent variation in both the states (Annexure III). The figure 4.25 (a) and (b) shows the importance of indicators responsible for the security of food availability in the respective states which is reflected from their weights obtained from principal component analysis. As revealed by the value of weights, irrigation intensity was the most important factor contributing to the security of food availability in both the states. The other indicators which influenced the security of food availability in the state of Punjab were cropping intensity and change in net sown area; whereas in Uttar Pradesh, population density was the second important indicator.

Few districts lying in the Malwa region like Moga, Muktsar etc. were highly secured in terms of food availability; however the districts which stood lower in terms of security of food availability were spread in all the three regions viz., Majha (Amritsar and Pathankot), Doaba (Jalandhar) and Malwa (SAS Nagar, Sangrur and Roopnagar) (Map 1a). The lowest cropping intensity in SAS Nagar (136.79%) and maximum decrease in the net sown area in Pathankot (by around 36 per cent) was probably the main reason behind less secured status of these districts in terms of food availability in the state of Punjab.

In case of Uttar Pradesh, most of the districts lying in the Western region of the state like Kasganj, Sambhal, Pilibhit etc. were highly secured in terms of food availability; however Bundelkhand (Chitrakoot, Hamirpur etc.), Central (Kanpur Nagar) and Eastern (Sonbhadra, Varanasi etc.) regions of the state were medium to lesser secured in terms of food availability (Map 1b). The lowest percentage of net irrigated area to the net sown area in Sonbhadra (29 %) and Chitrakoot (43%) in Uttar Pradesh pushed theses districts to the bottom in food availability security status.

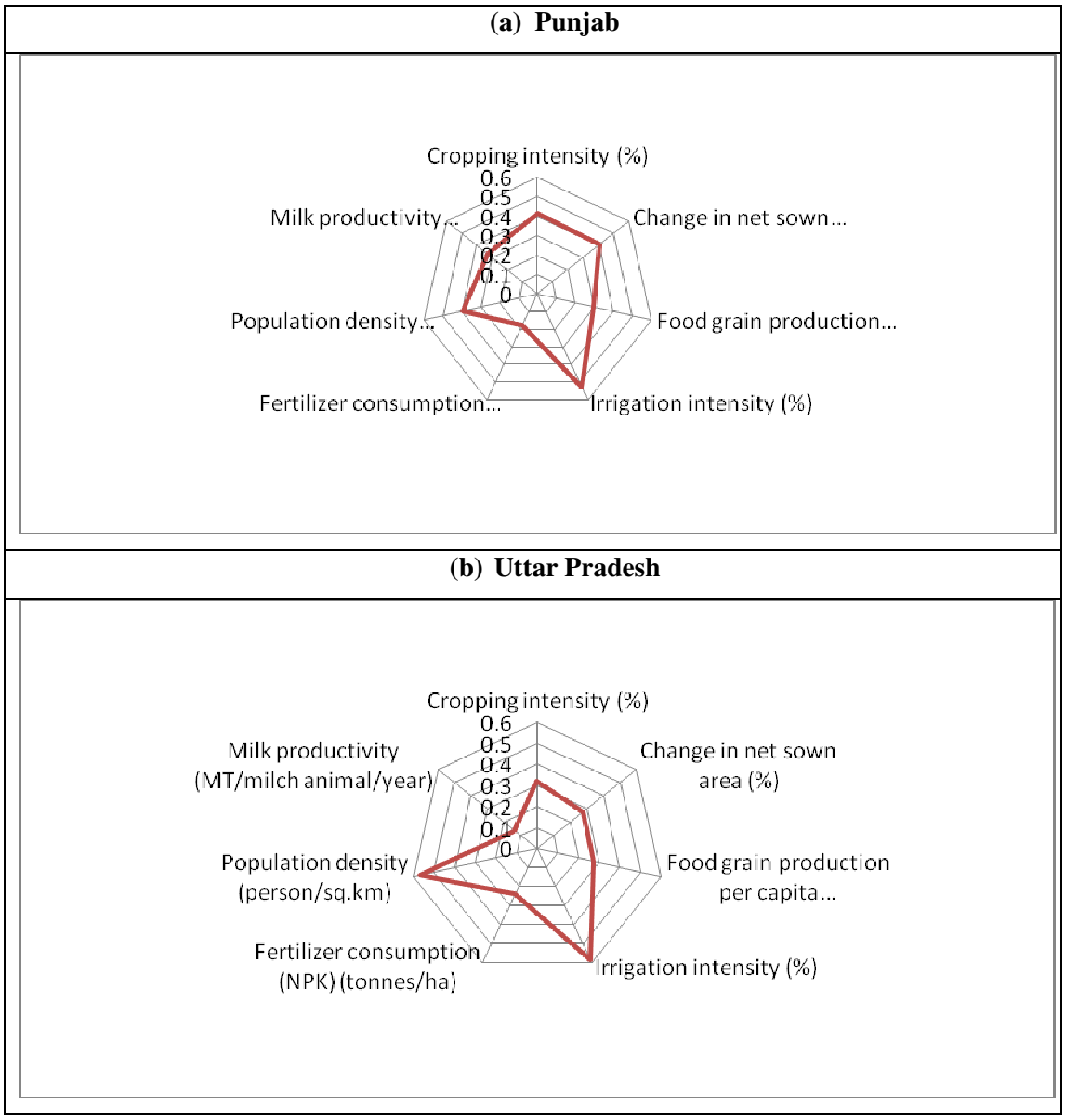
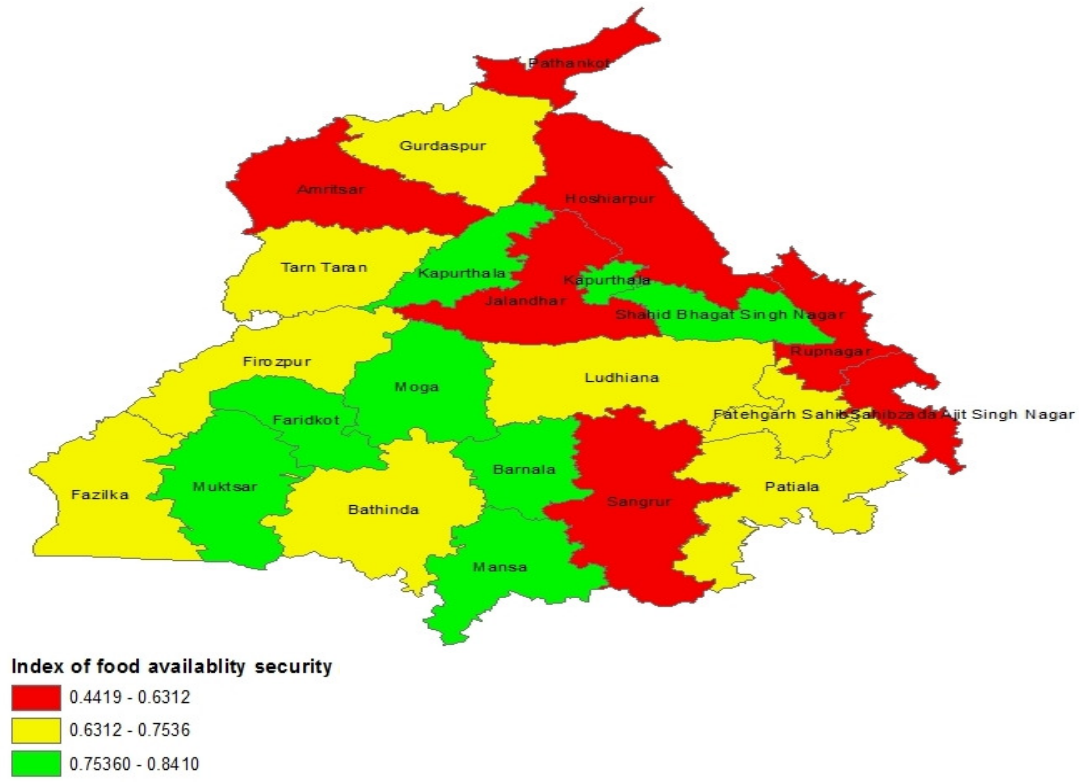


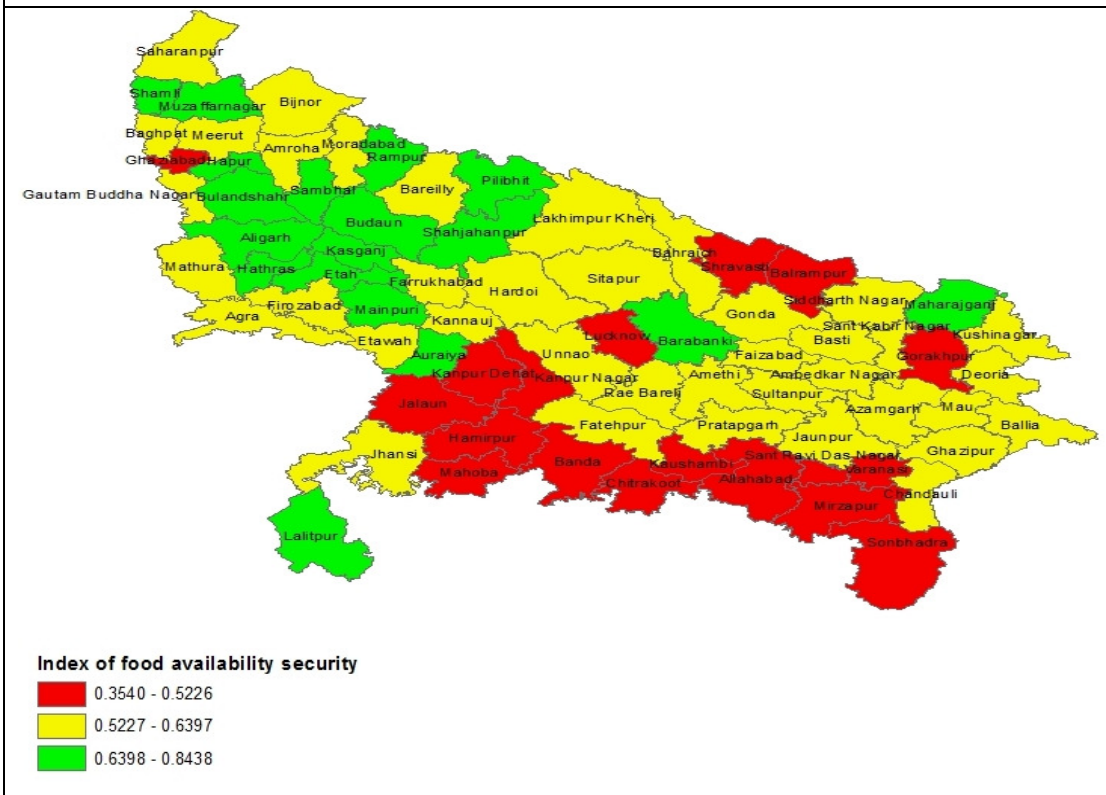
Fig 4.25: Weights for the indicators of food availability security

Map 1: District wise food availability security map of Punjab and Uttar Pradesh

(a) Punjab



(b) Uttar Pradesh



4.3.1.2 Index of food availability sustenance: The sustenance index of food availability in Punjab varied from a low level of 0.473 in Barnala to the highest level of 0.749 in Hoshiarpur, whereas in Uttar Pradesh it ranged from 0.413 in Hamirpur to 0.823 in Chandauli. The first principal component explained about 83 per cent variation in Punjab and around 90 per cent in Uttar Pradesh; and the weights obtained for each indicator from principal component analysis (PCA) is given in fig. 4.26 (a) and (b). Proportion of degraded area to geographical area emerged to be the most important indicator in Punjab. Unexploited groundwater for future use as well as coefficient of variation of monthly mean rainfall also affected the sustenance of food availability in the region. In Uttar Pradesh, growth rate of annual mean temperature gained prime importance in influencing sustenance of food availability. Other factors of high influence in the state were proportion of degraded area to geographical area and coefficient of variation of monthly mean rainfall. Interestingly, the climatic parameters, the consideration of which has been completely neglected in earlier literatures in constructing index at national (Vepa *et al* 2004) and regional level (Nasir *et al* 2014) gained importance in influencing the sustenance of food availability in the present study area.

Map 2(a) shows that most of districts in Punjab lying in the moderate range (0.5464-0.6717) of index of food availability sustenance; however few districts of Malwa region viz., Bhatinda, Faridkot, Muktsar etc. were observed to be highly sustained in terms of food availability. Since the percentage of degraded land to geographical area and unexploited groundwater for future use were the prime indicators and thus was determining the status of food availability sustenance of the districts of Punjab. Districts like Barnala and SAS Nagar have highest percentage of degraded land while in Sangrur and Jalandhar groundwater has been exploited to its maximum extent and therefore the above mentioned districts stood low in terms of food availability sustenance.

Map 2(b) shows that the districts in the Eastern region of Uttar Pradesh were ranked higher in the index of food availability sustenance and most of the districts in the Western region lied in the moderate range of the index. The district which stood lower in terms of food availability sustenance was in Bundelkhand region (Hamirpur, Jhansi etc.), Central region (Kanpur Nagar, Rae Bareli etc.) and Western region (Baghpat, Etawah, Auraiya). Percentage of degraded land to geographical area was the reason behind the low sustenance of these districts; apart from this, owing to the highest growth rate of annual mean temperature in Hamirpur, it stood least sustained in terms of food availability. The coefficient of variation of mean monthly rainfall in the aforesaid districts has also added to the lower sustenance of food availability.

As discussed in the methodology section, based on the two indices viz., index of food availability security and index of food availability sustenance, a composite sustainable food

availability index has been prepared. The district wise index values along with their ranking for the state of Punjab and Uttar Pradesh are given in Annexure- IV. Most of the districts lying in the western part of the Malwa region (Moga, Mansa, Bhatinda, Fazilka etc.) occupied relatively higher rank in sustainable food availability index than that of the other parts of the Punjab (Map 3a). As the districts of Jalandhar, Pathankot, Sangrur and SAS Nagar were rated low in security as well as sustenance of food availability, they also stood lower in sustainable food availability.

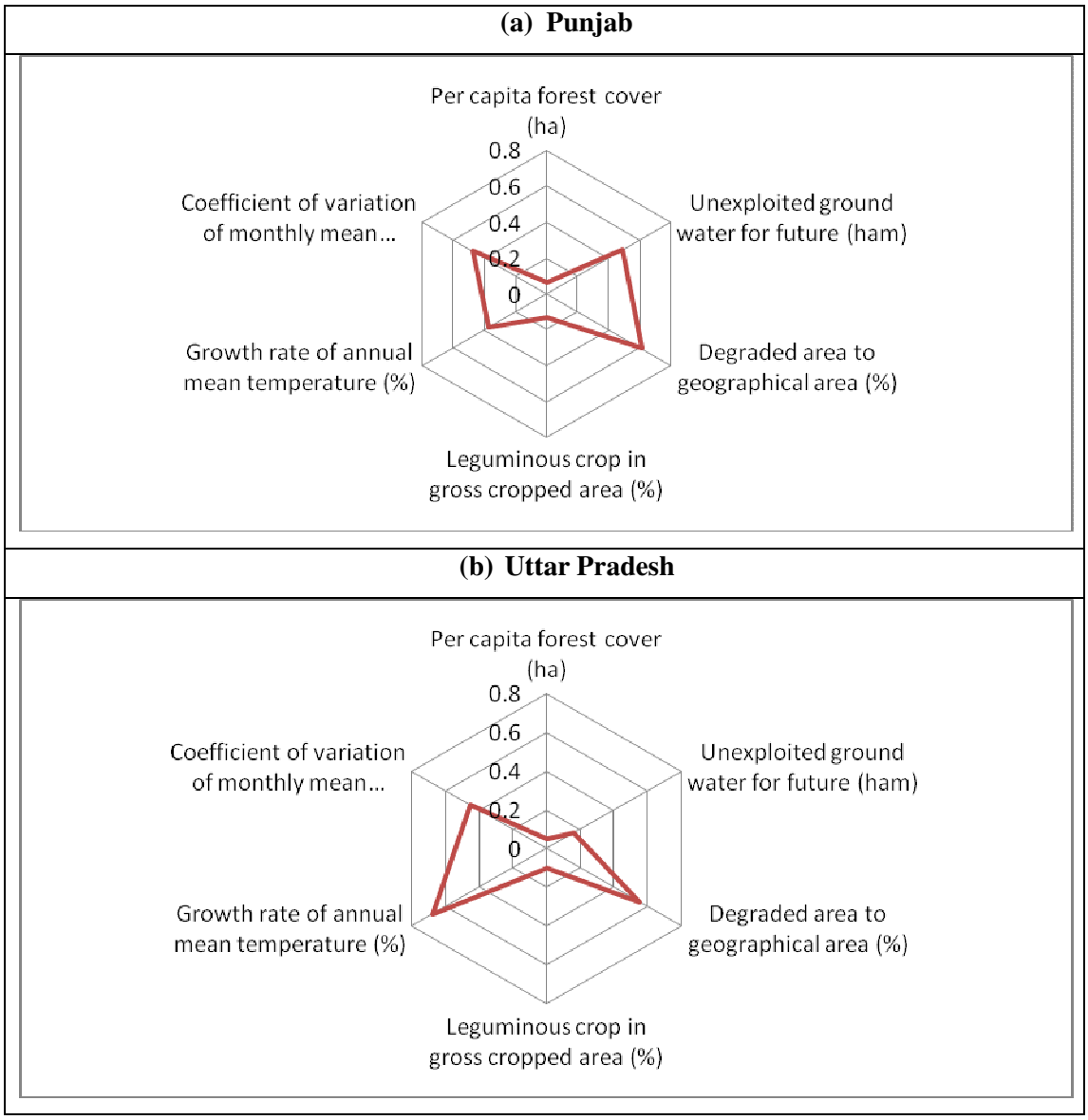
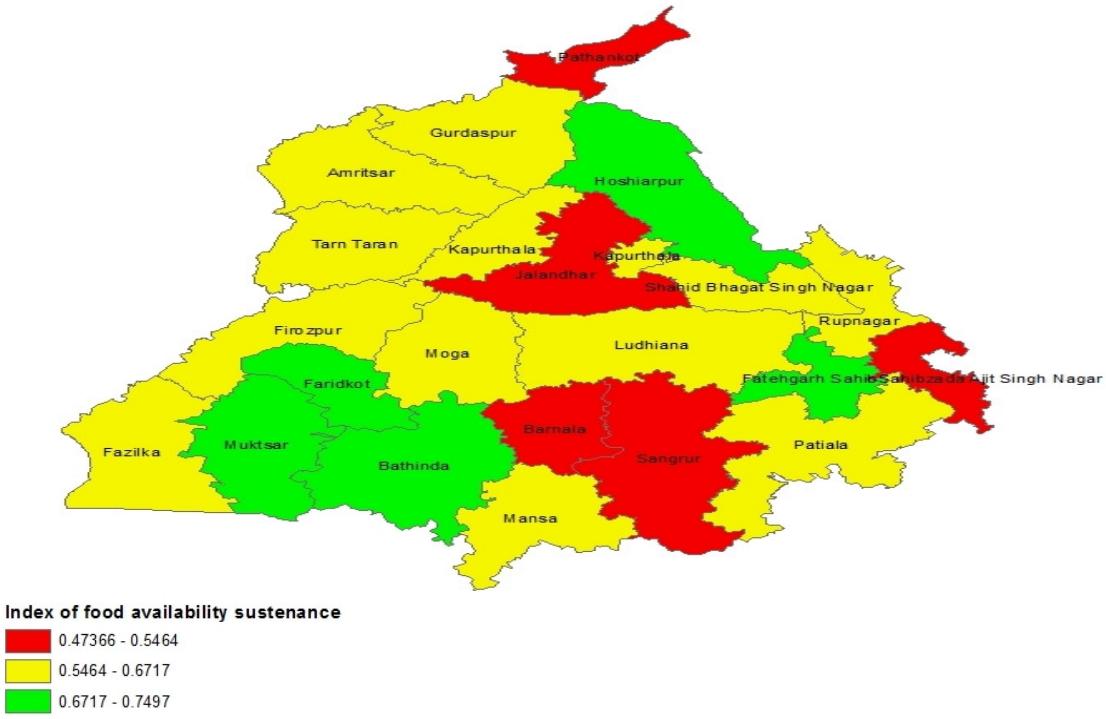


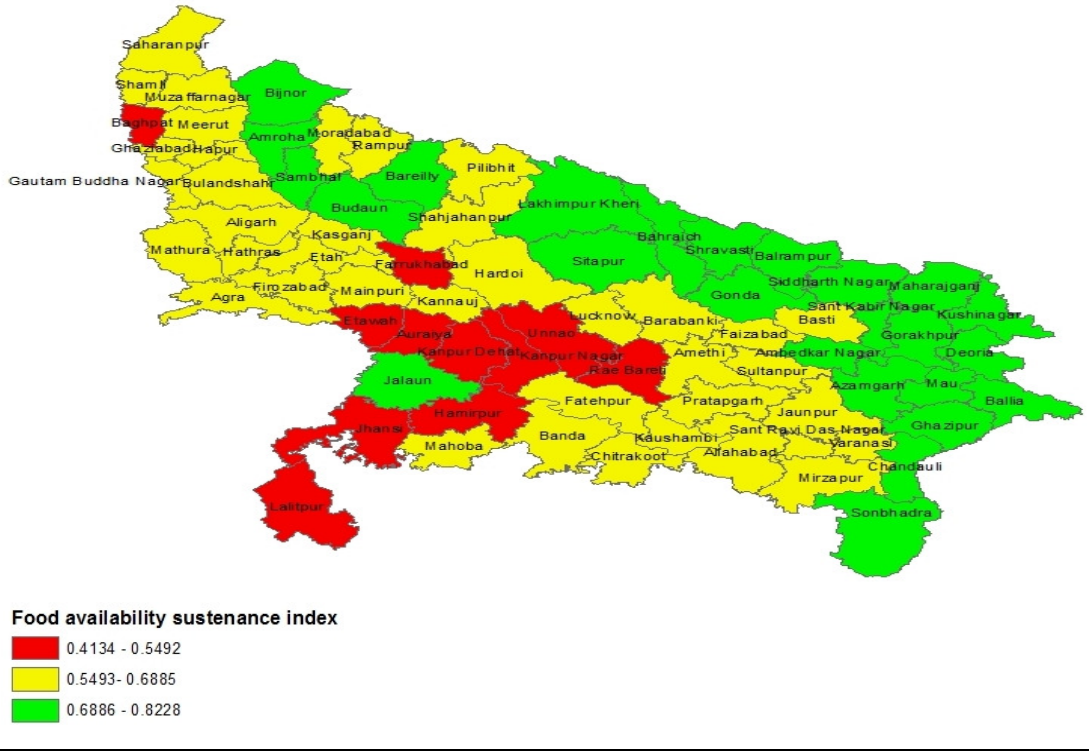
Fig. 4.26 Weights for the indicators of food availability sustenance

Map 2: District wise food availability sustenance map of Punjab and Uttar Pradesh

(a) Punjab

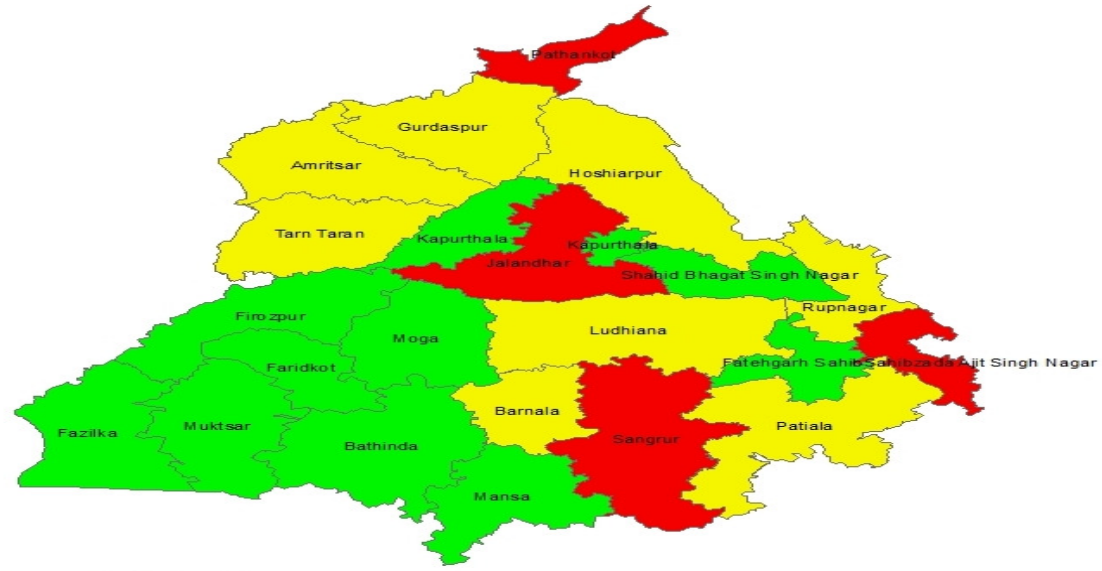


(b) Uttar Pradesh

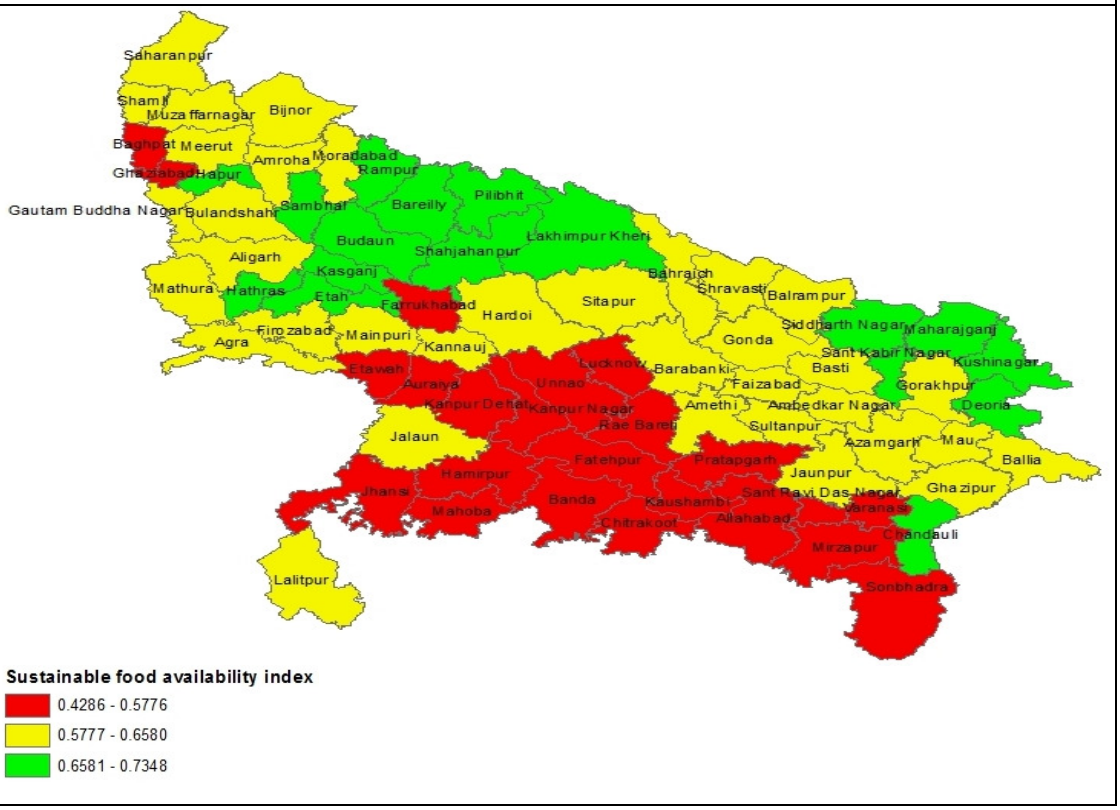


Map 3: District wise sustainable food availability map of Punjab and Uttar Pradesh

(a) Punjab



(b) Uttar Pradesh



In case of Uttar Pradesh, almost all of the districts lying in the Bundelkhand region and few districts of Central (Kanpur Nagar, Lucknow, Bara Banki etc.) and Eastern region (Sonbhadra, Mirzapur, Allahabad, Varanasi) were rated low in sustainable food availability. The districts of Baghpat and Ghaziabad which lie in the Western region of the state were also fell into lower range of sustainable food availability index owing to their lower indices value of food availability security and food availability sustenance. Further, few districts of north-western region (Pilibhit, Rampur, Bareilly) and north-eastern region (Maharajganj, Deoria, Kushinagar) were rated high in sustainable food availability.

4.3.2 Sustainable food access index

The index has been prepared from the two sub-indices i.e., index of food access security and index of food access sustenance. The following subsections present detail discussion on sub-indices for the study area.

4.3.2.1 Index of food access security: Weights obtained by PCA revealed that cross bred adoption rate as the most important indicator of food access security in Punjab (Fig. 4.27a), and number of small and marginal farmers in Uttar Pradesh for the same (Fig. 4.27b). The other indicators of high influence on food access security were below poverty line population, percentage of non agricultural workers and number of small and marginal farmers in Punjab whereas in the state of Uttar Pradesh, below poverty line population, percentage of non worker population and number of milch animals were the other prime influential factors.

Most of the districts in the Malwa region of Punjab were ranked lower in food access security (Map 4a); among which Mansa district occupied the lowest rank owing to the very low percentage of crossbred in total cattle population. The relatively higher rates of poverty and lower percentage of non agricultural workers in districts of Malwa region also added more to lower security of food access. The districts in the Majha region were either moderately or highly secured except Gurdaspur owing to higher number of population below poverty line, relatively higher number of small and marginal as well as non worker population in the district.

In case of Uttar Pradesh, almost all the districts in Central and Eastern region and few of the Western region (Shahjahanpur, Mainpuri, Budaun, Pilibhit, Etawah) were rated lower in the food access security index (Map 4b) owing to the relatively higher number of people living below poverty, large number of non working population and lesser number of milch animals. The districts lying in the Bundelkhand region and some of the districts in Eastern (Sonbhadra, Varanasi, Allahabad, Gorakhpur, Deoria) and Western (Bijnor, Etah, Moradabad, Sambhal, Bareilly) region fell into the moderate range (0.4113-0.5456) of food access security index.

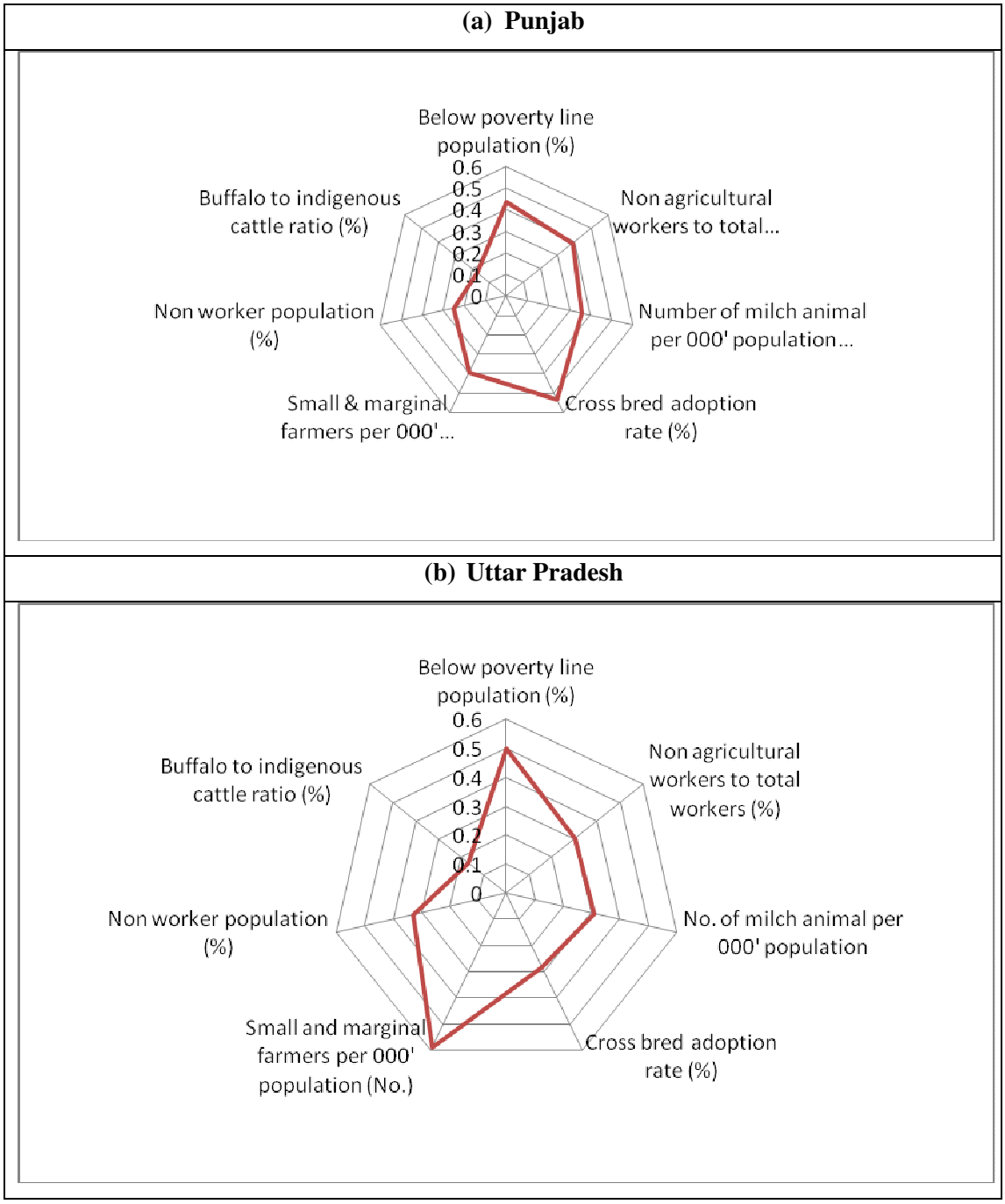
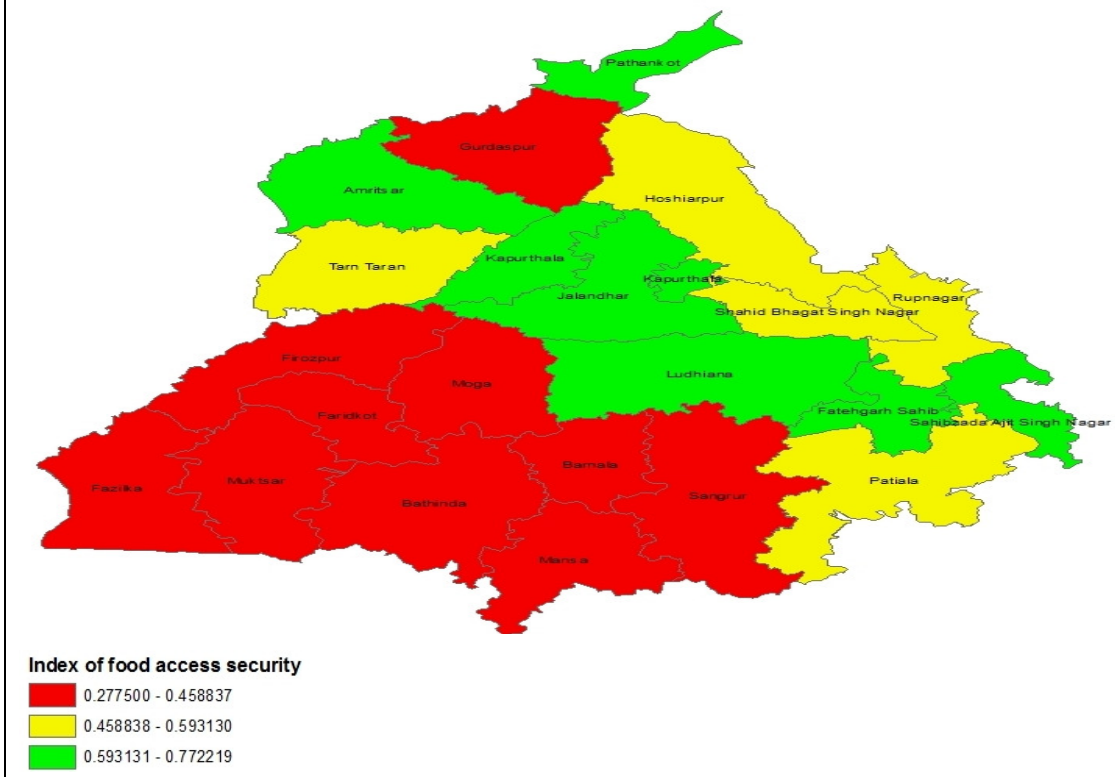


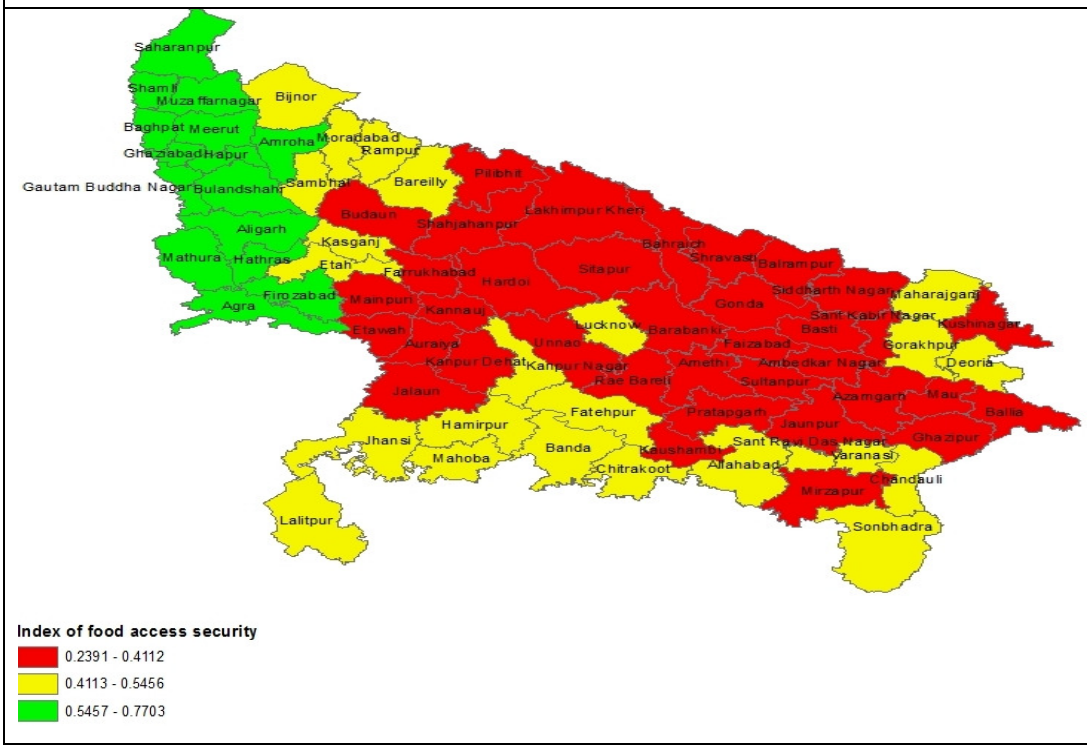
Fig. 4.27 Weights for the indicators of food access security

Map 4: District wise food access security map of Punjab and Uttar Pradesh

(a) Punjab



(b) Uttar Pradesh



4.3.2.2 Index of food access sustenance: The first principal component explained about 90 and 88 per cent variation in Punjab and Uttar Pradesh, respectively; and the weighs obtained for each indicator from principal component analysis (PCA) is given in Figure 4.28. The results revealed that the three indicators namely livestock density, percentage of landless labour households and instability in cereal production were the top three indicators in Punjab as well as in Uttar Pradesh, though their weightage value vary in both the states.

The districts in the northern part of Majha and Doaba region and two districts in eastern part of Malwa region (Rupnagar and SAS Nagar) were occupied lower position in the index of food access sustenance whereas the districts in the southern and central Malwa region were relatively higher sustained in terms of food access (Map 5a). The probable reason for lower sustenance of the districts were the larger number of livestock population, smaller percentage of landless labour households and higher instability in the cereal production; also smaller size of average holding added to lower sustenance in the regions.

Districts in the northern (Pilibhit, Kheri, Bahraich, Bareilly etc.) and north-western (Saharanpur, Bijnor, Meerut etc.) part of Uttar Pradesh were rated relatively high in terms of food access sustenance, whereas a large number of districts of central and eastern part of the state were in moderate range (0.5056 to 0.6005) in index of food access sustenance. It is important to mention here that a good number of districts of Uttar Pradesh (28 %), though sparsely located, were in bottom range of food access sustenance index (Map 5b).

The district wise value of sustainable food access index and their corresponding ranking for Punjab and Uttar Pradesh is given in Annexure IV. As the districts of Jalandhar and Ludhiana occupied relatively higher rank in food access security as well as sustenance indices, their sustainable food access index value were also higher (Map 6a). Besides, Kapurthala and Fatehgarh Sahib were also rated higher in terms of sustainable food access. Rest of the districts in Punjab fell into the moderate (0.5283-0.6233) and low (0.4288-0.5282) range of sustainable food access index.

In the state of Uttar Pradesh, most of the districts in Central and Eastern region which were rated relatively lower in the index of food access security also obtained lower value in the sustainable food access index; however some of the districts in the Western region (Muzaffarnagar, Saharanpur, Meerut, Bijnor etc.) were ranked higher in the index. Remaining all other districts in the Bundelkhand (Lalitpur, Jhansi, Mahoba etc.) and Eastern (Sonbhadra, Ballia, Deoria etc.) region lied in moderate range of sustainable food access index (Map 6b).

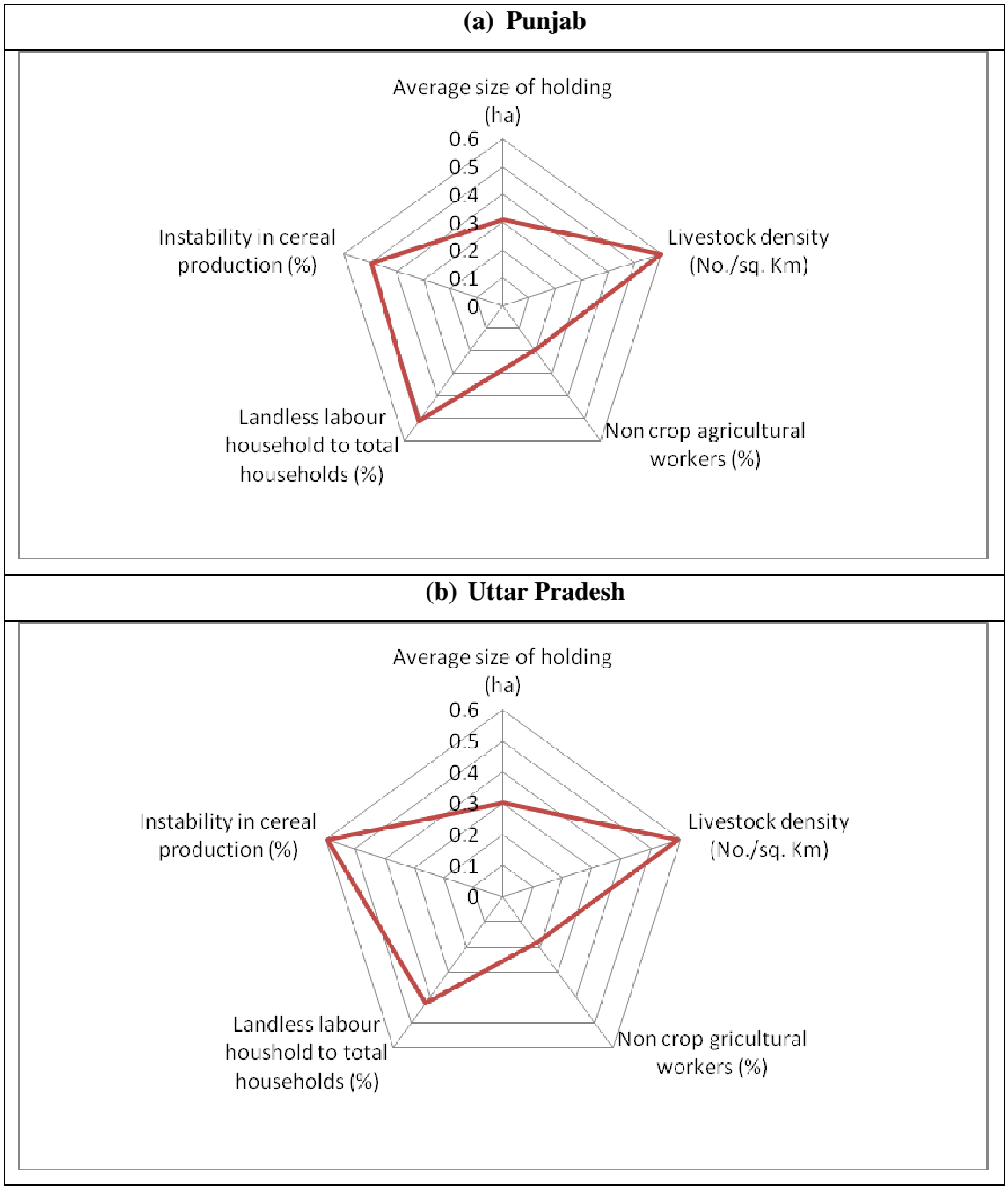
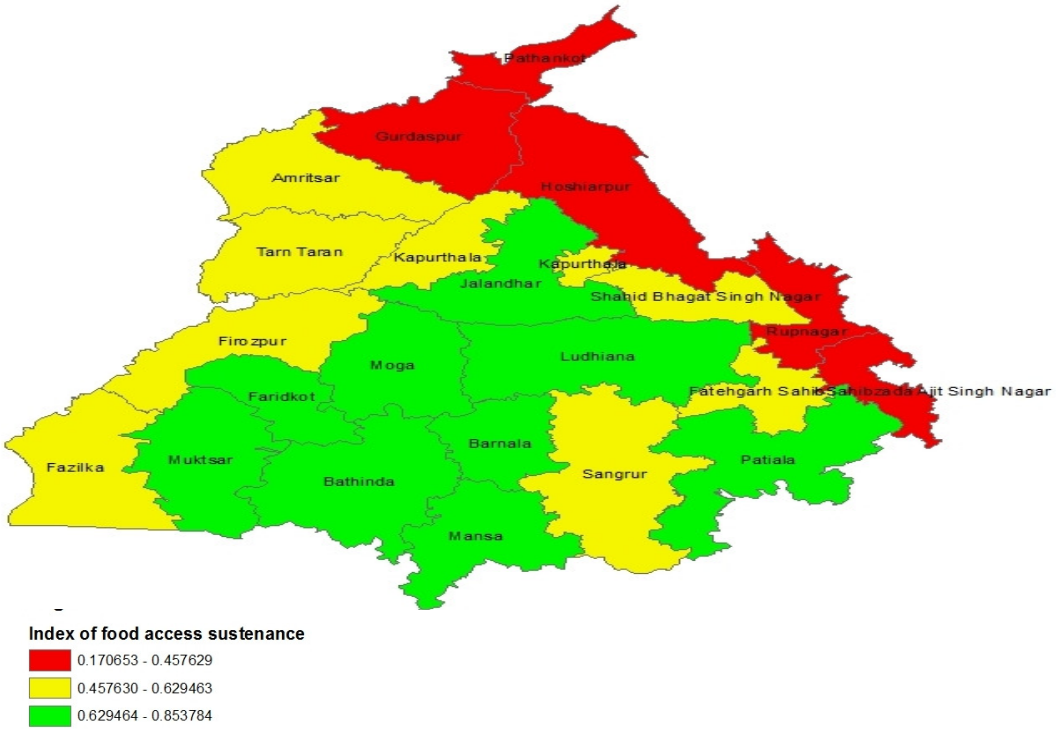


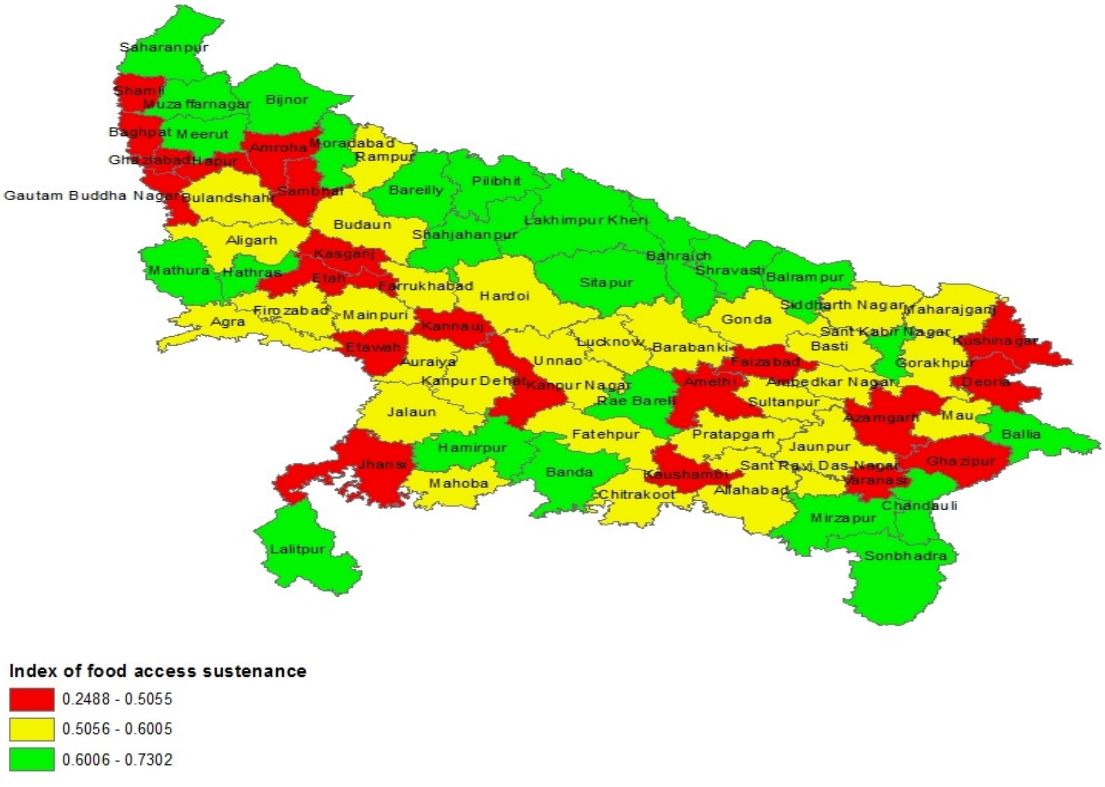
Fig. 4.28 Weights for the indicators of food access sustenance

Map 5: District wise food access sustenance map of Punjab and Uttar Pradesh

(a) Punjab

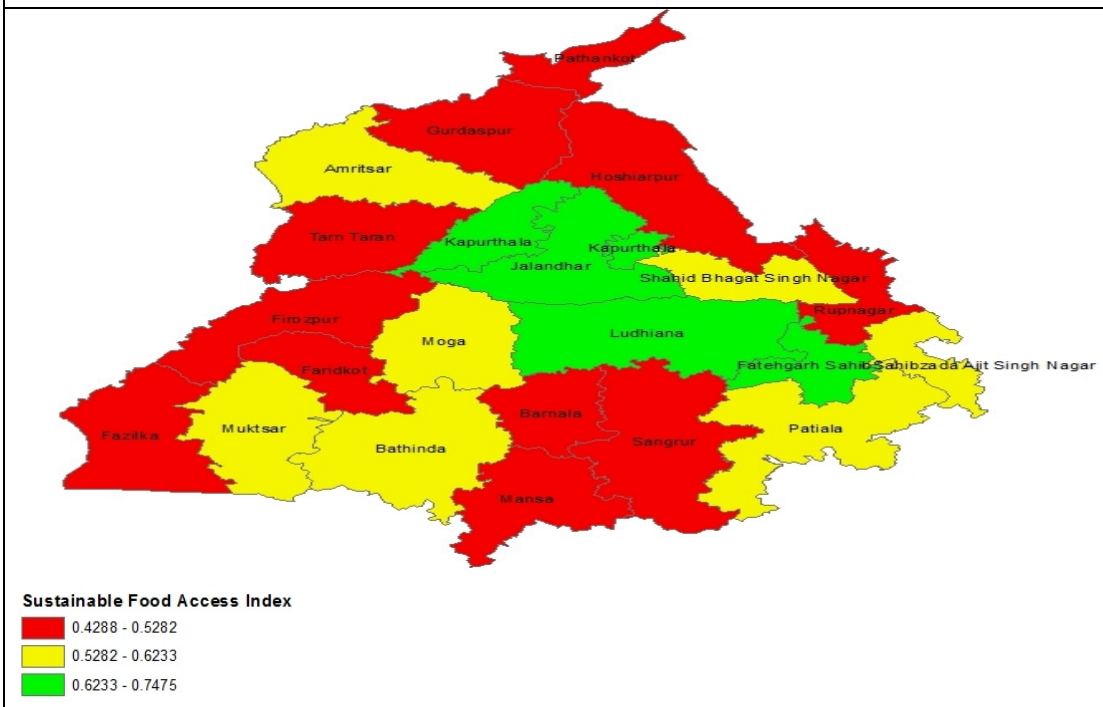


(b) Uttar Pradesh

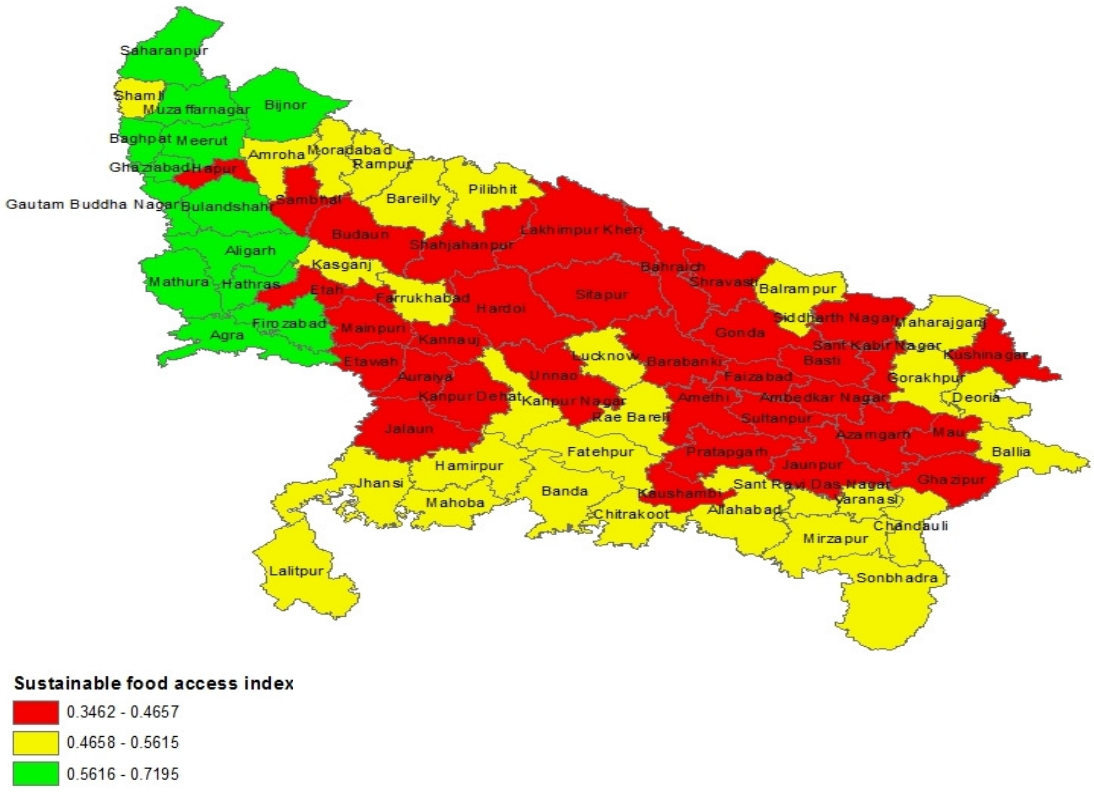


Map 6: District wise sustainable food access map of Punjab and Uttar Pradesh

(a) Punjab



(b) Uttar Pradesh



4.3.3 Food utilization index

The index was prepared for the state of Punjab and Uttar Pradesh using a total of four indicators viz., percentage access to safe drinking water, infant mortality rate, female literacy rate and availability of health infrastructure. In Punjab first principal component explained around 90 per cent variation (Annexure III) and weights obtained by PCA showed that access to safe drinking water and female literacy rate were equally important factors for utilization of food. The next important indicator was infant mortality rate (Fig. 4.29a) with weight 0.5160. Whereas in the state of Uttar Pradesh around 91 per cent variation was explained by the first principal component (Annexure III), and weights by PCA revealed that access to safe drinking water was the most important indicator. The other important indicators were female literacy rate and infant mortality rate (Fig. 4.29b). The availability of health infrastructure got lowest weight in both the states.

Almost all the districts in the western (Fazilka, Muktsar, Faridkot etc.) and some of the districts in the southern (Sangrur, Mansa etc.) part of Malwa region of Punjab were ranked lower in food utilization index owing to the poor female literacy rate in the region. The importance of literacy rate in determining food utilization was also highlighted by Nasir et al. (2014) in their study on food security in Punjab. The poor access of safe drinking water in these regions also added to their lower index value of food utilization (Map 7a).

In Uttar Pradesh districts lying in northern and north-eastern region were rated medium to low in terms of food utilization. Few districts in the southern part of the state (Lalitpur, Mahoba, Chitrakoot and Kaushambi) were also in the bottom range of the food utilization index (Map 7b). Good access of safe drinking water in the eastern districts (Ballia, Deoria, Azamgarh, Ghazipur etc.) and few districts in the western part (Agra, Etawah, Hathras etc.) of the state were the prime reason behind their higher index value of food utilization.

4.3.4 Sustainable Food Security Index

The sustainable food security index was estimated as weighted mean of the three composite indices viz., Sustainable Food Availability Index (SFAI), Sustainable Food Access Index (SFAcI) and Food Utilization Index (FUI). The district wise index values along with their ranking for the state of Punjab and Uttar Pradesh are given in Annexure IV. In Punjab, the sustainability of food security increased as one moves from southern to northern parts of the state. Most of the districts in Majha (Amritsar and Gurdaspur) and Doaba (Kapurthala, Hoshiarpur, Jalandhar and SBS Nagar) were ranked high in terms of sustainable food security whereas the districts in the western (Fazilka, Muktsar etc.) and southern (Mansa and Sangrur) part of Malwa region were rated low in sustainable food security index (Map 8a).

In case of Uttar Pradesh districts lying in extreme Western (Saharanpur, Baghpat, Meerut etc.) and Eastern (Ballia, Deoria, Mau etc.) parts of the state were highly sustainable in terms of overall food security while a large number of district fell into the moderate range of sustainable food security index (Map 8b).

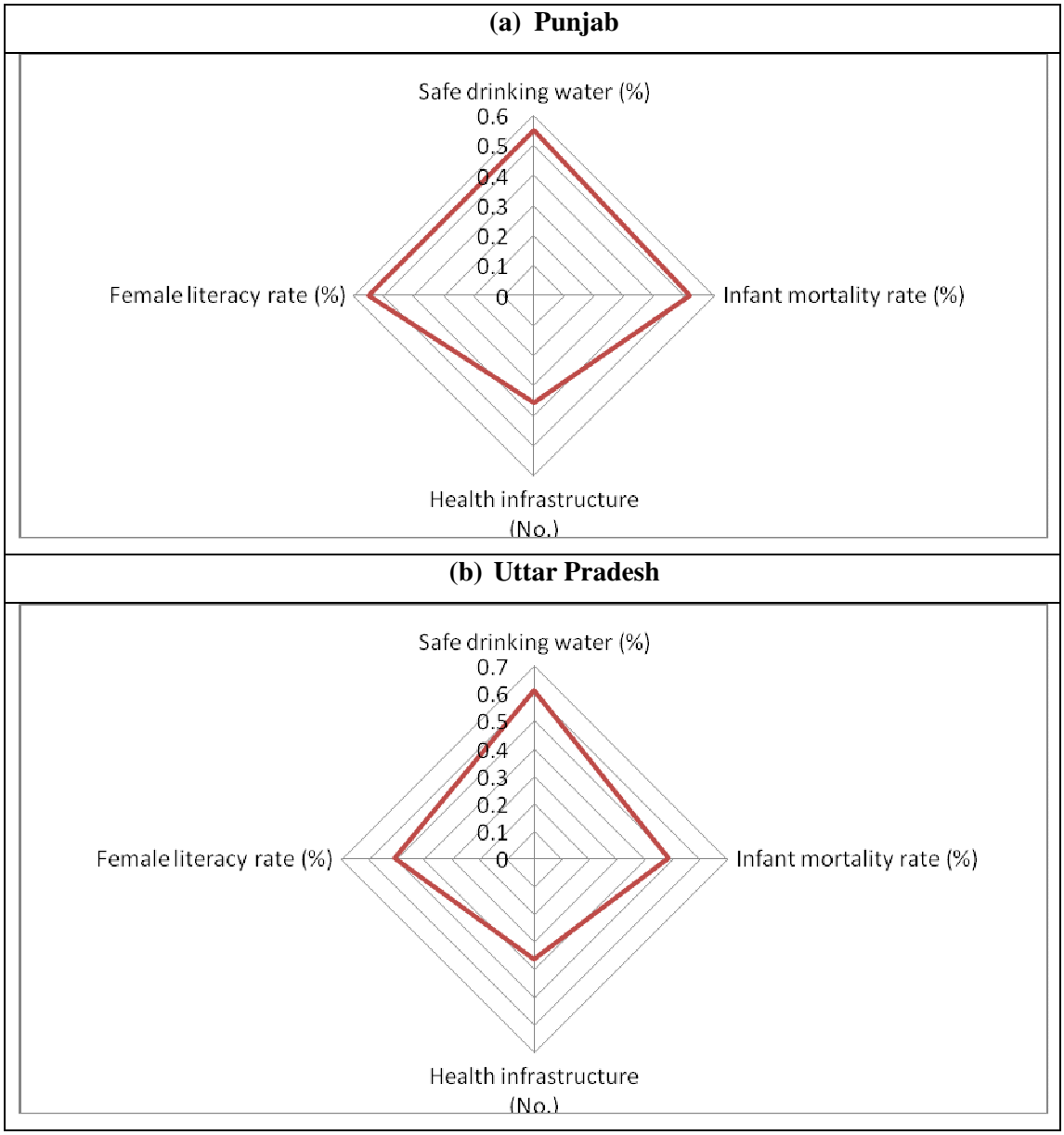
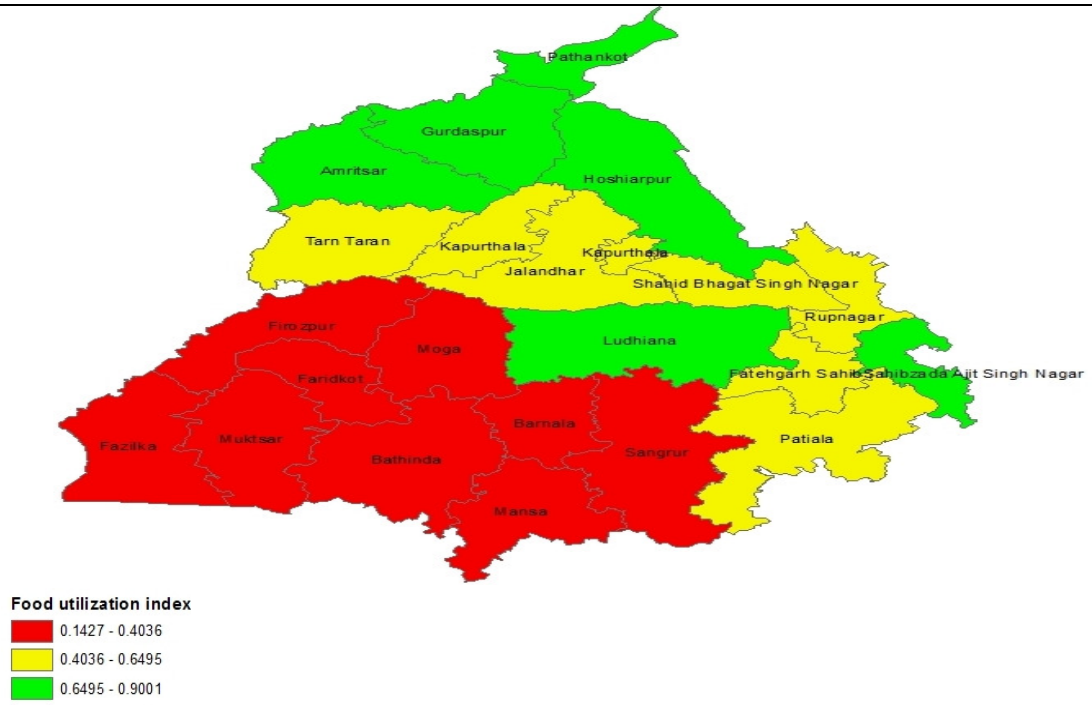


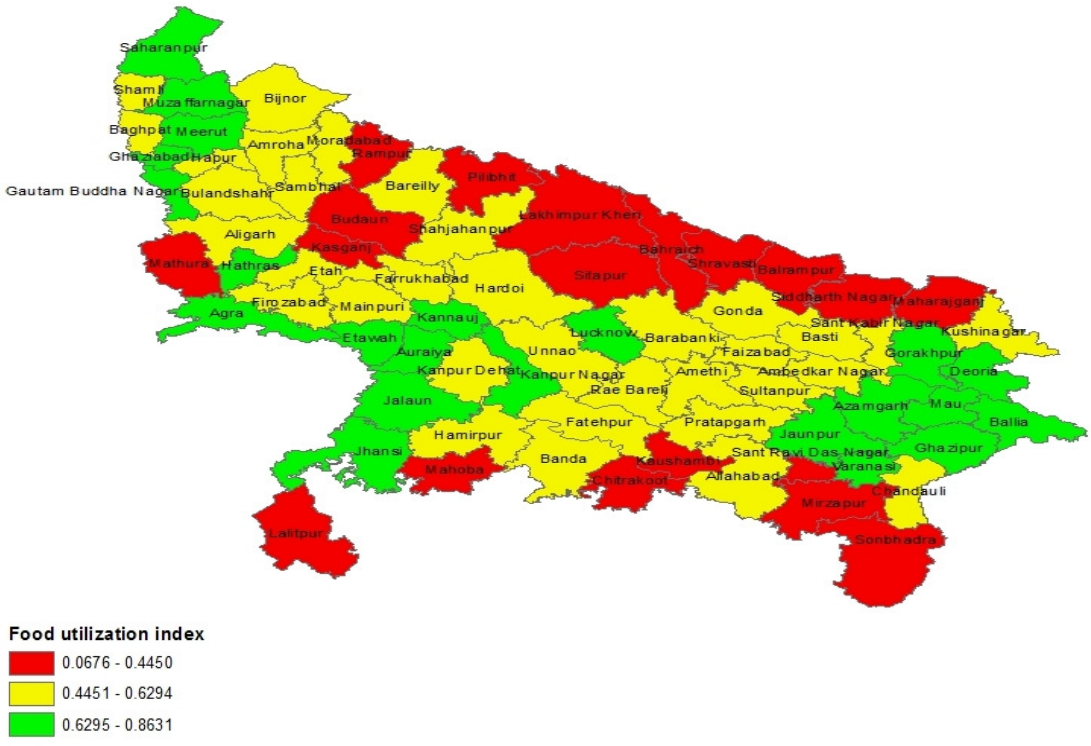
Fig. 4.29 Weights for the indicators of food utilization

Map 7: District wise food utilization map of Punjab and Uttar Pradesh

(a) Punjab

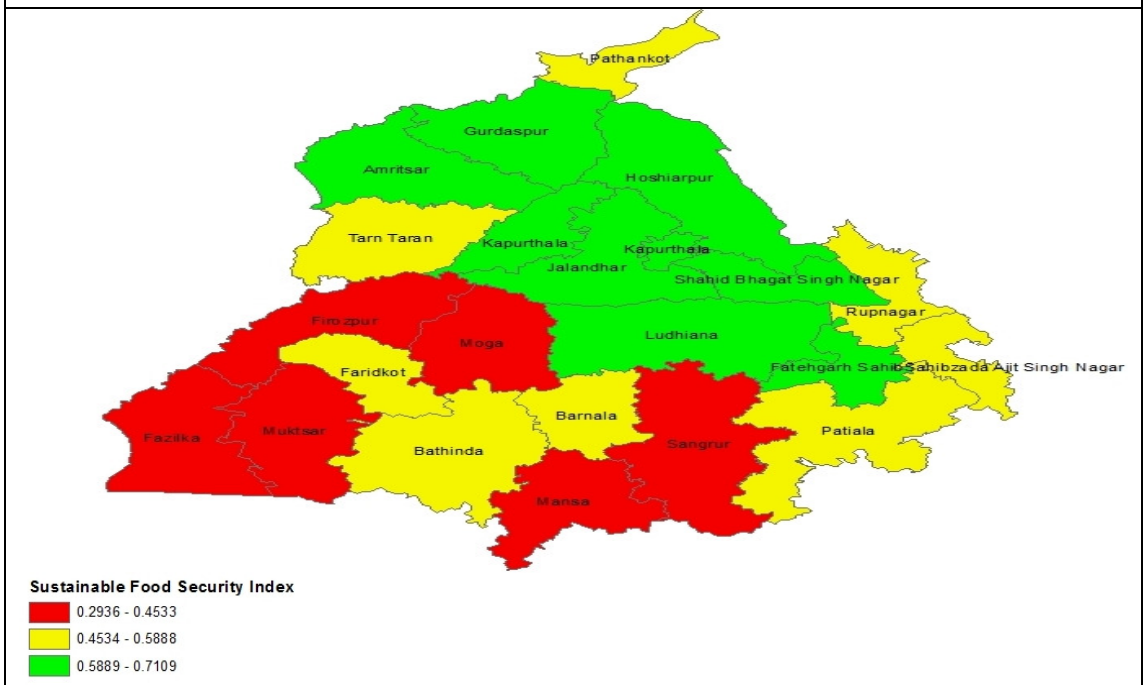


(b) Uttar Pradesh

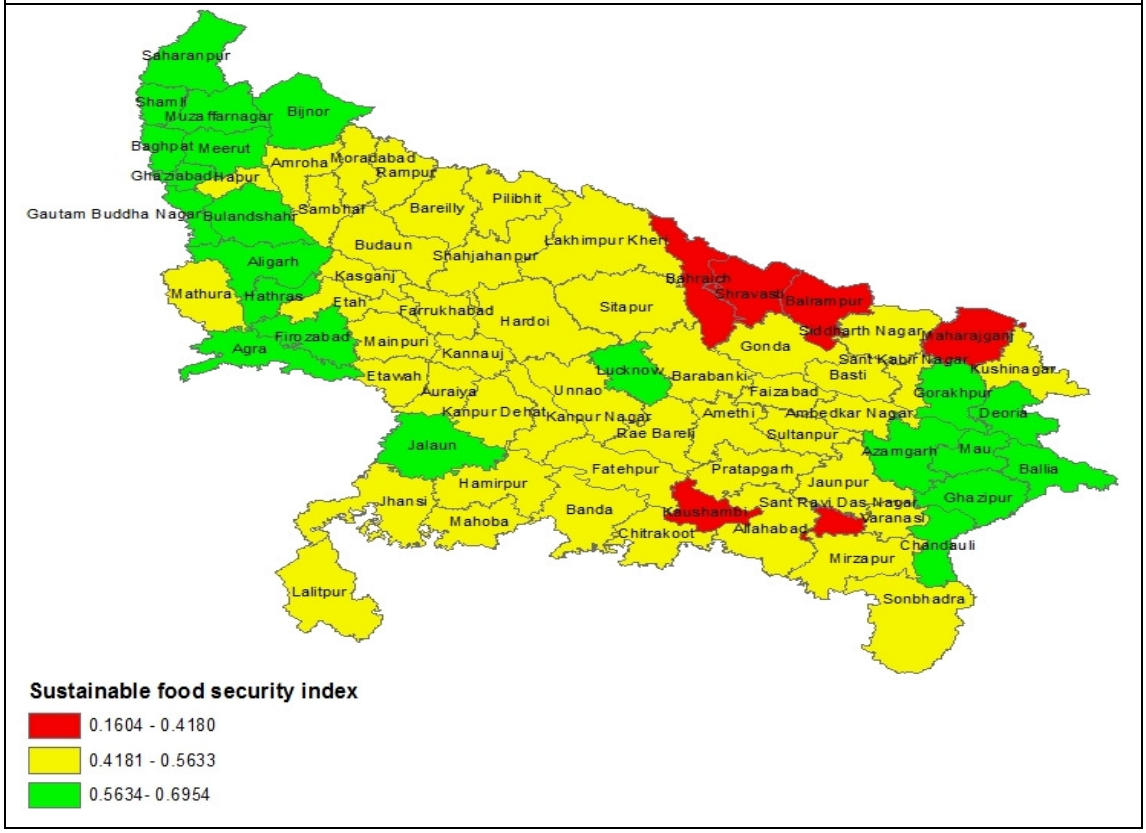


Map 8: District wise sustainable food security map of Punjab and Uttar Pradesh

(a) Punjab



(b) Uttar Pradesh



Numbers of districts in different sustainable food security class of the study area has been presented in Table 4.18. In Punjab 28 per cent of the districts were observed to be less sustainable in food security. On the contrary, in Uttar Pradesh only 8 per cent of the districts occupied the bottom range of sustainable food security index and most of them were moderately sustainable (61%).

Table 4.18: Number of districts in different sustainable food security class in Punjab and Uttar Pradesh

Regions	Total districts	Sustainable Food Security Class		
		High	Moderate	Low
Punjab	22	8 (36)	8 (36)	6 (28)
Uttar Pradesh	75	23 (31)	46 (61)	6 (8)

Note: Figures in parentheses are per cent of districts in different sustainable food security class

Relative status of sustainable food availability, sustainable food access and food utilization level of low sustainable food secure districts (Table 4.19) revealed that the districts in Punjab (Firozepur, Sangrur, Fazilka and Mansa) and Uttar Pradesh (Kaushambi, Bahraich and Shravasti) were less sustainable in terms of food security owing to the low sustainable food access as well as low utilization level.

Table 4.19: Relative status of components of sustainable food security in low sustainable food secure districts

Study area	Sustainable food security level	Districts	Sustainable food availability level	Sustainable food access level	Food utilization level
Punjab	Low	Firozepur	High	Low	Low
		Sangrur	Low	Low	Low
		Fazilka	High	Low	Low
		Moga	High	Moderate	Low
		Muktsar	High	Moderate	Low
		Mansa	High	Low	Low
Uttar Pradesh	Low	Maharajganj	High	Moderate	Low
		Sant Ravidas Nagar	Low	Moderate	Low
		Kaushambi	Low	Low	Low
		Balrampur	Moderate	Moderate	Low
		Bahraich	Moderate	Low	Low
		Shravasti	Moderate	Low	Low

However, few districts in the state of Punjab like Moga, Muktasar and in Uttar Pradesh (Maharajganj, Sant Ravidas Nagar and Balrampur) were having moderate access to food but have very poor utilization that pushes them in low sustainable food security class. Further, the high rating of the districts of Punjab and Maharajganj district of Uttar Pradesh in terms of sustainable food availability didn't helped much in pulling them from low sustainable food security status. Therefore the districts experiencing low food access with low or poor food utilization should be targeted areas and must be taken on priority for improving the sustainable food security status of the respective area.

4.4 Policy implications for sustainable food security in India as well as for the selected states

The findings of the present study have several implications for policy makers and scientific community for delineation of policy interventions for ensuring sustainable food security in the study area, which are as follows.

The crop wise assessment of growth rates of area, production and productivity of food grains at national level provides more accurate picture of the potential of nutri cereals in ensuring sustainable availability of food grains. The productivity led growth of nutri cereals over the entire study period, despite their significant decline in area over the time, suggests the need of area diversification towards the millets to meet the future consumption demand of growing population of the country. It is important to mention here that the nutri cereals currently sustain the livelihood of over 60% of small and marginal farmers in the country (NAAS 2013). The climate resilience nature of the millet crops and its nutritional advantages over other cereals are well documented (FAO 2018). Therefore, efforts must be directed to enhance the cultivated area under nutri cereals through the strategic choices of crop associations and rotations within the existing productions systems of farmers.

The crop wise estimation of growth rates of area, production and productivity of food grains for Punjab and Uttar Pradesh presents interesting picture of decelerated growth in production and productivity of food grains over the considered period in both the states. This suggests that the production and productivity performance of food grains in both the states is not sustainable in long run. Therefore, yield enhancement strategies should be properly taken up for ensuring long term availability of food grains in both the states.

Further, the stagnant yield growth of paddy in Punjab as well as in Uttar Pradesh largely caused its decelerated production growth in both the states. The decelerated yield growth of wheat in both the states would pose serious challenges in meeting the future availability need of the major staple crop at national level as well. The accelerated decline in area under nutri cereals and pulses in Uttar Pradesh and Punjab, respectively are another cause of concern. Hence, sincere efforts are required to enhance the yield potential of paddy and wheat crop. Research and development breakthrough for genetic advancement of the two

staple crops would be desirable policy intervention in this direction. The area diversification with nutri cereals and pulses in Uttar Pradesh and Punjab, respectively are another important policy prescription of the present study.

The assessment of sustainable food security status of both the states envisages several policy measures which are critical to improve the overall sustainability of food security in the study area. Bringing more area under irrigation is particularly important for Bundelkhand, and Sonbhadra district of Eastern region of Uttar Pradesh. As these regions are drought prone areas of the state (Gupta *et al* 2014); investment to create on-farm structures for harvesting, storage and distribution of rainwater would be more policy imperative. The findings of the study brought out that the degraded land in Punjab (particularly Malwa region) and Uttar Pradesh are looming threat for sustenance of food availability in the state, hence strict land use strategy and efficient watershed management practices should be the top policy priority for reclaiming degraded lands.

As the injudicious use of the ground water resources has also emerged as crucial factor that challenges sustenance of food availability in Punjab; strategies for optimizing its use is recommended to taken up at priority basis. Optimal crop mix plans with pulses and nutri cereals will go a long way to arrest the exploitation of ground water resources in the state. Alternate wetting and drying (Tabbal *et al* 2002), adoption of System of Rice Intensification (SRI) (Thakur *et al* 2010a, Zhao *et al* 2010), use of tensiometres (Hira *et al* 2006, 2007) and direct plantation of paddy (Cabangon *et al* 2002, Johnkutty *et al* 2002, Singh *et al* 2005) are some of the other widely suggested measures for efficient use of ground water.

The study draws attention of the policy makers for development of regional climate change adaptation and resilience enhancement strategies, especially for Bundelkhand region of Uttar Pradesh where variability in the climatic parameters is comparatively higher than other parts of the study area.

As the study establishes that improving food access and utilization capacity are more critical than food availability for ensuring sustainable food security of the study area, the findings of the study will help the decision makers at all level of decision making in targeting the districts where appropriate measures are to be taken up for strengthening the food access and utilization capacity of people.

Promoting crossbred adoption and providing off-farm employment opportunities in Malwa region of Punjab; and endorsing farmers coalition vis. a vis. strategic interventions for minimizing instability in production system in northern Majha and Doaba region of the state should be prior policy options towards ensuring sustainable food access. Likewise, for reducing the rural poverty ratio and improving the milch herd population, which found to be critical for improving food access security in eastern and central region of Uttar Pradesh, measures to create more off-farm employment opportunities and promotion of sex semen

technology would be more policy imperative.

Besides, in the regions which are rated low in terms of food utilization in the study area, all stakeholders should enact measures to improve female literacy rate and access of safe drinking water for ensuring overall sustainable food security of the study regions.

CHAPTER V

SUMMARY

Over the past decade, there has been improvement in the global food security scenario still it is not free from challenges and issues (Tandon *et al* 2017) which is undoubtedly indicated by the growing hunger population and food insecurity. The number of people suffering from chronic hunger has shot up from 804 million in 2016 to 821 million in 2017 in the world (FAO 2018). The severity of the issue for the entire world is clearly reflected from the commitments of United States to ensure global food security by 2030 (FAO 2016a) through placing ‘‘end hunger, achieve food security & improved nutrition and promote sustainable agriculture’’ as one of the core objective of Sustainable Development Goal (SDG).

Food security has been the central theme of agricultural development policy in India ever since mid-1960s. The glorious journey of the nation in achieving self sufficiency in terms of food production and minimizing the fluctuations is well documented, however a large chunk of population in the country have been reported to face chronic food insecurity (Radhakrishna and Reddy 2004). Studies of national interest have reported the untapped potential of agricultural sector that need to be exploited in an environmentally sustainable manner in order to reduce poverty, hunger and improve the food security scenario of the country (Nadav 1996, Irz *et al* 2001, Majid 2004).

Nevertheless, various research studies are being increasingly taken up to assess the food security from national perspective and current availability of food has been accorded prime place for ensuring food security. The sustainability of food availability and access which is crucial for ensuring the food security of future generation has been largely ignored. Precise assessment of food security and its sustainability status at regional level is prerequisite for strategic planning and prioritizing allocation of resources for ensuring food security for the future generations. Therefore, the present study **“Food Security and Sustainability: A Comparative Study of Punjab and Uttar Pradesh”** has been undertaken in the most populous and productive agricultural production system of the country i.e. Punjab and Uttar Pradesh with the following objectives:

1) To examine the trends in the pattern of food grain production and distribution overtime in India.
2) To analyze the trends and contribution of selected states in food grain production in India.
3) To study the developments in sustainability of food security in selected states.
4) To draw policy implications for sustainable food security in India as well as the selected states.

The study was based on secondary data. District wise secondary data for area, production and productivity of food grains (paddy, wheat, nutri cereals, total cereals and pulses), district wise consumption of NPK fertilizers, district wise data on unexploited ground water for future use, land holdings, livestock parameters, demographic parameters, female literacy rate, infant mortality rate, percentage of population having access to safe drinking water, availability of health infrastructure and climatic parameters were either collected or estimated, as per the requirement , using information from various published and unpublished sources.

The compound annual growth rate (CAGR) of area, production and productivity of food grains over a comprehensive period of TE1990/91 - TE2016/17 and for the three decadal periods viz., TE1990/91-2000/01 (PI), TE2000/01-2010/11 (PII) and TE 2010/11-2016/17 (PIII) at national level and for the selected states viz., Punjab and Uttar Pradesh, was estimated using semi-log model. The acceleration and deceleration in the growth rates for the selected states over each time period was estimated using the log-quadratic model. The inclusion of time squared term in the log-quadratic model gave rise to the problem of multicollinearity. This is avoided by the normalization of time in mean deviation form, that is, by setting t = 0 at the midpoint of the series that allows the time (t) and its square (t^2) to become orthogonal.

The district wise composite index of food security for the selected states has been constructed from its components – food availability, access and utilization to assess the food security as well as its sustainability. The indicators and its relation with each component of food security were selected from wide range of indicators used in previous standard studies and discussion with experts. Principal Component Analysis (PCA) technique was used to assign weights to indicators of each dimension of food security.

The main findings of the study are summarized as follows:

The area under food grains at national level witnessed significant downward trend during the whole period mainly due to slump in area under the total food grains during PI i.e., TE 1990/91 to 2000/01. The actual area under total cereals remain more or less stagnated; however, trends in growth rate shows that it declined significantly (CAGR 0.09%) during the entire study period. Among cereals crops, the area under paddy and wheat registered significant upward trend while in case of nutri cereals area exhibited significant downward trend over the comprehensive period under study. Besides, the area under pulses has increased significantly at an annual rate of 0.32 per cent over the entire study period. The trend in the production of food grains shows an impressive and significant growth (CAGR 1.60 %) during the whole period as well as in the sub periods with the highest growth being registered in PIII (CAGR 1.70 %). The crop wise analysis reveals that production of paddy, wheat, nutri cereals and pulses significantly increased during the overall period, though the pulses production

registered splendid improvement after 2000/01 i.e. in sub periods PII and PIII contrary to the negative growth in PI. The significant positive growth in productivity of food grains, nutri-cereals and total cereals signifies their yield-led growth in production over the time as area under the respective category has significantly declined during the same period. Further, during the overall period, both the procurement and distribution of rice and wheat has increased with annual rate of above 5 per cent.

During the overall period, the growth in the production of food grains in Punjab is driven by both increases in area as well as productivity. Although the annual growth in area, production and productivity found to be positive and significant; their growth has decelerated significantly over the time. The crop wise analysis reveals that area, production and productivity of total cereals, paddy and wheat registered significant positive growth over the time, though at decelerated rate with productivity growth of paddy being exceptionally stagnated during the same period. Interestingly, the nutri cereals in Punjab witnessed productivity led growth over the whole study period as reflected by significant increase and decrease in production and area of the nutri cereals in the state during the same time scale. Further, nonetheless the productivity of pulses has increased; its production and area has declined significantly at an accelerated rate during the entire study period.

In case of Uttar Pradesh, food grains witnessed significant productivity led growth, since the growth in area has declined significantly at an accelerated rate during the overall study period. The crop wise analysis shows significant increase in the production of paddy and wheat owing to the significant increase in the area as well as productivity of the same during the entire study period. Despite the accelerated and significant growth in productivity of nutri cereals over the whole period, the production significantly turned down due to marked decline in its area during the same period. In case of pulses, significant decline in area resulted in slump in production of pulses in the state during the two and half decades under consideration.

During the entire study period the growth in the area as well as production share of food grains in the state of Punjab and Uttar Pradesh declined significantly. The share of both the states in area under total cereals has significantly increased over the time, however, the growth in area share in Punjab witnessed significant declining trend during the same time period. The growth in production share in both the states also registered declining trend over the entire time scale under study. The crop wise analysis further brought out the fact that while area and production share of Punjab in case of paddy marked significant rise over the time, only significant increase in area share of Uttar Pradesh under paddy has been observed. In case of wheat and nutri cereals, area and production share of both the states has significantly turned down over the time. Further, area as well as production share of Punjab for pulses has increased though non significantly over the whole considered period, the share

of Uttar Pradesh in area and production for pulses registered significant declining trend during the same time period.

As far as sustainable food security is concerned, the weights obtained for each indicator from principal component analysis (PCA) showed that irrigation intensity was the most important factor contributing to the security of food availability in both the states viz., Punjab and Uttar Pradesh. Few districts lying in the Malwa region like Moga, Muktsar etc. were highly secured in terms of food availability; however the districts which stood lower in terms of security of food availability were spread in all the three regions viz., Majha (Amritsar and Pathankot), Doaba (Jalandhar) and Malwa (SAS Nagar, Sangrur and Roopnagar). In case of Uttar Pradesh, most of the districts lying in the Western region of the state like Kasganj, Sambhal, Pilibhit etc. were highly secured in terms of food availability; however Bundelkhand (Chitrakoot, Hamirpur etc.), Central (Kanpur Nagar) and Eastern (Sonbhadra, Varanasi etc.) regions of the state were medium to lesser secured in terms of food availability. Proportion of degraded area to geographical area emerged to be the most important indicator in Punjab, whereas in Uttar Pradesh, growth rate of annual mean temperature gained prime importance in influencing sustenance of food availability. Most of districts in Punjab lying in the moderate range of index of food availability sustenance; however few districts of Malwa region viz., Bhatinda, Faridkot, Muktsar etc. were observed to be highly sustained in terms of food availability. The districts in the Eastern region of Uttar Pradesh were ranked higher in the index of food availability sustenance and most of the districts in the Western region lied in the moderate range of the index. The district which stood lower in terms of food availability sustenance was in Bundelkhand region (Hamirpur, Jhansi etc.), Central region (Kanpur Nagar, Rae Bareli etc.) and Western region (Baghpat, Etawah, Auraiya).

The composite sustainable food availability index has been prepared from its sub indices i.e., index of food availability security and index of food availability sustenance. Most of the districts lying in the western part of the Malwa region (Moga, Mansa, Bhatinda, Fazilka etc.) occupied relatively higher rank in sustainable food availability index than that of the other parts of the Punjab. In case of Uttar Pradesh, almost all of the districts lying in the Bundelkhand region and few districts of Central (Kanpur Nagar, Lucknow, Bara Banki etc.) and Eastern region (Sonbhadra, Mirzapur, Allahabad, Varanasi) were rated low in sustainable food availability. The districts of Baghpat and Ghaziabad which lie in the Western region of the state were also fell into lower range of sustainable food availability index. While, few districts of north-western region (Pilibhit, Rampur, Bareilly) and north-eastern region (Maharajganj, Deoria, Kushinagar) were rated high in sustainable food availability.

In the index of food access security, cross bred adoption rate emerged as the most important indicator in Punjab; and number of small and marginal farmers in Uttar Pradesh.

Most of the districts in the Malwa region of Punjab were ranked lower while the districts in the Majha region were either moderately or highly secured except Gurdaspur in food access security. In Uttar Pradesh, almost all the districts in Central and Eastern region and few of the Western region (Shahjahanpur, Mainpuri, Budaun, Pilibhit, Etawah) were rated lower in the food access security index whereas the districts lying in the Bundelkhand region and some of the districts in Eastern (Sonbhadra, Varanasi, Allahabad, Gorakhpur, Deoria) and Western (Bijnor, Etah, Moradabad, Sambhal, Bareilly) region fell into the moderate range. Livestock density, percentage of landless labour households and instability in cereal production were the top three indicators determining food access sustenance in Punjab as well as in Uttar Pradesh, though their weightage value vary in both the states. The districts in the northern part of Majha and Doaba region and two districts in eastern part of Malwa region (Rupnagar and SAS Nagar) were occupied lower position in the index of food access sustenance whereas the districts in the southern and central Malwa region were relatively higher sustained in terms of food access. Districts in the northern (Pilibhit, Kheri, Bahraich, Bareilly etc.) and north-western (Saharanpur, Bijnor, Meerut etc.) part of Uttar Pradesh were rated relatively high in terms of food access sustenance.

The sustainable food access index was also constructed using its two sub indices namely index of food access security and index of food access sustenance. The districts of Jalandhar, Ludhiana, Kapurthala and Fatehgarh Sahib in Punjab occupied relatively higher rank in sustainable food access index. In the state of Uttar Pradesh, most of the districts in Central and Eastern region were rated relatively lower in the sustainable food access index; however some of the districts in the Western region (Muzaffarnagar, Saharanpur, Meerut, Bijnor etc.) were ranked higher in the index.

The access to safe drinking water and female literacy rate were equally promising factors in determining the utilization of food in the state of Punjab; whereas in Uttar Pradesh only access to safe drinking water was the most important indicator. Almost all the districts in the western (Fazilka, Muktsar, Faridkot etc.) and some of the districts in the southern (Sangrur, Mansa etc.) part of Malwa region of Punjab were ranked lower in food utilization index. In Uttar Pradesh, few districts in the southern part (Lalitpur, Mahoba, Chitrakoot and Kaushambi) were in the bottom range of the food utilization index while the districts in Eastern region (Ballia, Deoria, Azamgarh, Ghazipur etc.) and few in the Western part (Agra, Etawah, Hathras etc.) of the state were rated higher.

In Punjab, the sustainability of food security increased as one moves from southern to northern parts of the state. Most of the districts in Majha (Amritsar and Gurdaspur) and Doaba (Kapurthala, Hoshiarpur, Jalandhar and SBS Nagar) were ranked high in terms of sustainable food security whereas the districts in the western (Fazilka, Muktsar etc.) and southern (Mansa and Sangrur) part of Malwa region were rated low in sustainable food security index. In case

of Uttar Pradesh districts lying in extreme Western (Saharanpur, Baghpat, Meerut etc.) and Eastern (Ballia, Deoria, Mau etc.) parts of the state were highly sustainable in terms of overall food security while a large number of district fell into the moderate range of sustainable food security index.

Conclusions and policy suggestions:

Based on the above findings, following policy interventions are suggested for all the stakeholders for better management and targeting of resources in order to ensure as well as enhance sustainability of food security status in Punjab and Uttar Pradesh:

- The potential of nutri cereals in ensuring the sustainable food availability of food grains suggests the need of area diversification towards the millets to meet the future consumption demand of growing population of the country. Therefore, efforts must be directed to enhance the cultivated area under nutri cereals through the strategic choices of crop associations and rotations within the existing productions systems of farmers.
- The crop wise estimation of growth rates of area, production and productivity of food grains for Punjab and Uttar Pradesh shows that the production and productivity performance of food grains in both the states is not sustainable in long run. Therefore, yield enhancement strategies should be properly taken up for ensuring long term availability of food grains in both the states.
- Further sincere efforts are required to enhance the yield potential of paddy and wheat crop since the productivity growth of both the crops has stagnated during the considered study period. Research and development breakthrough for genetic advancement of the two staple crops would be desirable policy intervention in this direction. The area diversification with nutri cereals and pulses in Uttar Pradesh and Punjab, respectively are another important policy prescription of the present study.
- The results of the study will support the decision makers at all level of decision making in identifying the least sustainable food secure districts of the most populous and productive agriculture ecosystem in India viz., Punjab and Uttar Pradesh for the development of suitable policy measures to strengthen the food security status in the respective states.
- The study draws the attention of policy makers that investment to create on-farm structures for harvesting, storage and distribution of rainwater would be more policy imperative in Bundelkhand, and Sonbhadra district of Eastern region of Uttar Pradesh to ensure food availability security.
- For reclamation of degraded land in Punjab (especially Malwa region) and Uttar Pradesh strict land use strategy and efficient watershed management practices should be the top policy priority.
- Alternate wetting and drying adoption of system of rice intensification (SRI), use of

tensiometres and direct plantation of paddy are some of the widely suggested measures for optimum and efficient use of groundwater resources in Punjab for sustenance of food availability.

- Regional climate change adaptation and resilience enhancement strategies, especially for Bundelkhand region of Uttar Pradesh recommended to be taken up.
- Promoting crossbred adoption and providing off-farm employment opportunities in Malwa region of Punjab; and endorsing farmers coalition vis. a vis. strategic interventions for minimizing instability in production system in northern Majha and Doaba region of the state should be prior policy options towards ensuring sustainable food access.
- Likewise, for reducing the rural poverty ratio and improving the milch herd population, which found to be critical for improving food access security in eastern and central region of Uttar Pradesh, measures to create more off-farm employment opportunities and promotion of sex semen technology would be more policy imperative.
- Besides, in the regions which are rated low in terms of food utilization in the study area, all stakeholders should enact measures to improve female literacy rate and access of safe drinking water for ensuring overall sustainable food security of the study regions.

Future researchable issues

As no study is complete in itself, hence there is always a scope for improvement over previous research. In the present work, sustainable food security was assessed with utmost care regarding selection of methodology along with consideration of number of indicators relevant to the study area i.e. Punjab and Uttar Pradesh. The same can be replicated at national level as well as for other states and also across agro-climatic zones within the country to assess precise regional food security status; since regional level estimate is prerequisite for strategic planning and prioritizing allocation of resources for ensuring food security for the future generations.

The present study focuses on the food security, its component and their relative status in terms of present security and future sustenance in the study area; nutrition which is an important dimension pertaining to food security has not been taken into consideration. One can think of studying the sustainability of food and nutrition security together as it will be of great help for policy makers in eradicating hunger and thus meeting the Sustainable Development Goals (SDG).

Further, as the indicator selected in the present study is bound to change with time, the present assessment in the selected states can be revisited in future. Lastly, the scope of primary data based evaluation of sustainable food security with suitable choice of indicators in the study area cannot be denied.

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ANNEXURE-I

Year wise creation of new districts in Punjab

State	**New District**	**Year**	**Craved out from District (%)**
Punjab	Fatehgarh Sahib	1992-93	Ludhiana (2.82) Ropar/Rupnagar (2.37) Patiala (19.17)
	Mansa	1992-93	Bhatinda (36.84)
	Moga	1995-96	Faridkot (35.98) Firozpur (9.65)
	Muktsar	1995-96	Faridkot (37.73)
	Nawansahar(SBS Nagar)	1995-96	Hoshiarpur (10.57) Jalandhar (18.62)
	Mohali (SAS Nagar)	2005-06	Ropar/Rupnagar (75) Patiala (25)
	TarnTaran	2005-06	Amritsar (47.36)
	Barnala	2006-07	Sangrur (27.85)
Uttar Pradesh	Amroha	1997-98	Moradabad (28.04)
	Ambedkar Nagar	1995-96	Azamgarh (0.80) Faizabad (53.86)
	Auraiya	1997-98	Etawah (47.07)
	Baghpat	1997-98	Meerut (29.88)
	Balrampur	1997-98	Gonda (38.30)
	Chandauli	1997-98	Varanasi (26.23)
	Chitrakoot	1997-98	Banda (32.01)
	Gautam Buddha Nagar	1997-98	Bulandshahr (13.39) Gaziabad (17.32)
	Hathras	1997-98	Aligarh (25.68) Mathura (14.53)
	Kannauj	1997-98	Farrukhabad (47.37)
	Kaushambi	1997-98	Allahabad (20.78)
	Kushinagar	1994-95	Deoria (50.82)
	Mahoba	1995-96	Hamirpur (39.69)
	Sant Kabir Nagar	1997-98	Basti (38.42) Siddharth Nagar (5.85)
	Sant Ravidas Nagar	1994-95	Varanasi (20.17)
	Shravasti	1997-98	Bahraich (33.41)
	Kasganj	2008	Etah(26.79)
	Hapur	2011	Ghaziabad(34.14)
	Sambhal	2012	Moradabad (39.12)
	Shamli	2011	Muzaffarnagar (26.22)
	Amethi	2010	Sultanpur (44.63) Raebareli (23.49)

Note: Figure in parentheses indicate proportion of parent district(s) used in creation of new district

Source: Administrative Atlas of India, Census of India, 2011.

ANNEXURE-II

Economic Region of Punjab and Uttar Pradesh

S.No.	Region	Districts
1.	Majha	Amritsar, Gurdaspur, Pathankot and Tarn Taran
2.	Malwa	Barnala, Bathinda, Fatehgarh Sahib, Faridkot, Fazilka, Firozpur, Ludhiana, Mansa, Moga, SAS Nagar (Mohali), Muktsar, Patiala, Rupnagar and Sangrur
3.	Doaba	Jalandhar, Kapurthala,Hoshiarpur and SBS Nagar (Nawanshahr)

Source: Kaler, 2016

S.No.	Region	Districts
1.	Western	Agra, Mainpuri, Firozabad, Aligarh, Kasganj, Bareilly, Badaun, Bulandshar, Etah, Etawah, Farrukhabad, Mathura, Meerut, Ghaziabad, Muradabad, Pilibhit, Rampur, Muzaffarnagar, Saharanpur, Bijnor, Shahjahanpur, Baghpat, Gautam Buddha Nagar, Hathras, Amroha, Kannauj, Auriya
2.	Central	Bara Banki, Fatehpur, Hardoi, Kanpur Nagar, Kanpur Dehat, Kheri, Lucknow, Raebareli, Sitapur, Unnao
3.	Eastern	Allahabad, Kaushambi, Azamgarh, Mau, Ballia, Bahraich, Basti. Siddharth Nagar, Deoria, Faizabad, Ghazipur, Gonda, Gorakhpur, Maharajganj, Jaunpur, Mirzapur, Sonbhadra, Pratapgarh, Sultanpur, Varanasi, Balrampur, Shravasti, Chandauli, Sant Ravidas Nagar, Kushi Nagar, Sant Kabir Nagar, Ambedkar Nagar
4.	Bundelkhand	Jhansi, Jalaun, Hamirpur, Mohaba, Banda, Chtirakoot, Lalitpur

Source: Government of Uttar Pradesh, 2009

ANNEXURE-III

First principal component of different dimensions of sustainable food security

Dimensions of sustainable food security	Punjab		Uttar Pradesh	
	Eigen value	Proportion	Eigen value	Proportion
Food availability security	70.00	0.9045	152.04	0.9190
Food availability sustenance	40.32	0.8329	126.46	0.9068
Food access security	43.41	0.8266	101.27	0.8354
Food access sustenance	35.53	0.8999	104.90	0.8840
Food utilization	27.61	0.8986	94.16	0.9140

ANNEXURE-IV

Districts wise rank and indices of sustainable food availability and its components in Punjab

District	Index of Food Availability Security		Index of Food Availability Sustenance		Sustainable Food Availability Index	
	Index value	Rank	Index value	Rank	Index value	Rank
Faridkot	0.8068	5	0.7326	2	0.7734	1
Muktsar	0.8288	2	0.7047	5	0.7730	2
Kapurthala	0.8109	3	0.6718	6	0.7483	3
Bathinda	0.7373	10	0.7260	3	0.7322	4
Moga	0.8410	1	0.5968	16	0.7311	5
Fatehgarh Sahib	0.7457	9	0.7107	4	0.7299	6
Nawanshahr	0.7733	7	0.6483	9	0.7171	7
Mansa	0.7764	6	0.6071	15	0.7002	8
Firozepur	0.7536	8	0.6275	12	0.6969	9
Fazilka	0.7191	11	0.6677	7	0.6959	10
Hoshiarpur	0.6246	16	0.7497	1	0.6809	11
Gurdaspur	0.6658	14	0.6486	8	0.6581	12
Barnala	0.8089	4	0.4737	22	0.6580	13
Tarn Taran	0.6889	13	0.6194	14	0.6576	14
Patiala	0.6929	12	0.5786	17	0.6414	15
Ludhiana	0.6313	15	0.6415	10	0.6359	16
Rupnagar	0.6027	17	0.6398	11	0.6194	17
Amritsar	0.5983	18	0.6221	13	0.6090	18
Jalandhar	0.5644	20	0.5465	18	0.5564	19
Sangrur	0.5727	19	0.5311	19	0.5540	20
Pathankot	0.5574	21	0.5138	21	0.5378	21
SAS Nagar	0.4419	22	0.5155	20	0.4751	22

Districts wise rank and indices of sustainable food availability and its components in Uttar Pradesh

District	Index of Food Availability Security		Index of Food Availability Sustenance		Sustainable Food Availability Index	
	Index value	Rank	Index value	Rank	Index value	Rank
Kasganj	0.8439	1	0.6017	53	0.7349	1
Chandauli	0.6390	20	0.8228	1	0.7217	2
Maharajganj	0.6510	17	0.8005	5	0.7183	3
Sambhal	0.7097	3	0.7156	19	0.7123	4
Kheri	0.6398	19	0.7911	6	0.7079	5
Pilibhit	0.7096	4	0.6885	26	0.7001	6
Budaun	0.6572	16	0.7416	15	0.6952	7
Siddharth Nagar	0.5973	38	0.8085	3	0.6923	8
Bareilly	0.6133	28	0.7472	13	0.6736	9
Kushi Nagar	0.5657	52	0.8046	4	0.6732	10
Shahjahanpur	0.6843	6	0.6594	35	0.6731	11
Hathras	0.6652	12	0.6745	32	0.6694	12
Deoria	0.5916	41	0.7567	12	0.6659	13
Etah	0.6686	10	0.6606	34	0.6650	14
Rampur	0.6618	15	0.6671	33	0.6641	15
Hapur	0.6646	13	0.6579	36	0.6616	16
Sant Kabir Nagar	0.5767	51	0.7626	9	0.6603	17
Ambedkar Nagar	0.6244	25	0.6992	24	0.6581	18
Gonda	0.6104	31	0.7104	22	0.6554	19
Azamgarh	0.6078	32	0.7119	20	0.6546	20
Mau	0.5943	40	0.7282	17	0.6546	21
Mainpuri	0.7061	5	0.5901	55	0.6539	22
Amroha	0.6053	34	0.7112	21	0.6529	23
Bulandshahr	0.6708	9	0.6282	44	0.6516	24
Amethi	0.6280	23	0.6788	28	0.6508	25
Ballia	0.5594	54	0.7586	11	0.6490	26
Bahraich	0.5359	55	0.7866	7	0.6487	27
Bijnor	0.6038	35	0.7027	23	0.6483	28
Sitapur	0.6012	36	0.6984	25	0.6450	29
Shravasti	0.5055	61	0.8104	2	0.6427	30
Moradabad	0.6074	33	0.6835	27	0.6416	31
Gorakhpur	0.5227	58	0.7863	8	0.6413	32
Ghazipur	0.5790	49	0.7172	18	0.6412	33
Bara Banki	0.6767	7	0.5960	54	0.6404	34
Shamli	0.6746	8	0.5891	56	0.6362	35
Lalitpur	0.7398	2	0.5066	68	0.6349	36
Meerut	0.5980	37	0.6766	30	0.6334	37
Muzaffarnagar	0.6426	18	0.6134	50	0.6295	38

Hardoi	0.6322	22	0.6253	47	0.6291	39
Sultanpur	0.5840	45	0.6750	31	0.6250	40
Jaunpur	0.5911	42	0.6551	37	0.6199	41
Faizabad	0.6111	30	0.6278	45	0.6186	42
Firozabad	0.5900	43	0.6505	39	0.6173	43
Aligarh	0.6633	14	0.5580	64	0.6159	44
Kannauj	0.5845	44	0.6534	38	0.6155	45
Saharanpur	0.5947	39	0.6180	48	0.6052	46
Basti	0.5816	48	0.6333	43	0.6049	47
Jalaun	0.4930	64	0.7284	16	0.5989	48
Mathura	0.6277	24	0.5621	63	0.5982	49
Balrampur	0.4581	66	0.7625	10	0.5951	50
Agra	0.5834	46	0.6060	52	0.5936	51
Gautam Buddha Nagar	0.5357	56	0.6424	41	0.5837	52
Auraiya	0.6682	11	0.4670	72	0.5777	53
Unnao	0.6199	26	0.5238	66	0.5767	54
Jhansi	0.6123	29	0.5157	67	0.5688	55
Pratapgarh	0.5598	53	0.5759	60	0.5670	56
Farrukhabad	0.5787	50	0.5493	65	0.5655	57
Baghpat	0.6324	21	0.4818	70	0.5646	58
Mirzapur	0.5109	59	0.6099	51	0.5554	59
Kaushambi	0.5055	60	0.6161	49	0.5553	60
Mahoba	0.4531	68	0.6785	29	0.5545	61
Fatehpur	0.5345	57	0.5667	62	0.5490	62
Etawah	0.6144	27	0.4618	73	0.5457	63
Sant Ravidas Nagar	0.4560	67	0.6343	42	0.5362	64
Allahabad	0.5050	62	0.5727	61	0.5354	65
Raebareli	0.5832	47	0.4671	71	0.5310	66
Sonbhadra	0.3540	75	0.7470	14	0.5309	67
Varanasi	0.4521	69	0.6258	46	0.5303	68
Lucknow	0.4650	65	0.5878	57	0.5203	69
Banda	0.4049	72	0.6452	40	0.5130	70
Kanpur Dehat	0.5026	63	0.4959	69	0.4995	71
Ghaziabad	0.4024	73	0.5761	59	0.4805	72
Chitrakoot	0.3649	74	0.5842	58	0.4636	73
Kanpur Nagar	0.4229	71	0.4445	74	0.4327	74
Hamirpur	0.4410	70	0.4134	75	0.4286	75

Districts wise rank and indices of sustainable food access and its components in Punjab

District	Index of Food Access Security		Index of Food Access Sustenance		Sustainable Food Access Index	
	Index value	Rank	Index value	Rank	Index value	Rank
Jalandhar	0.7722	1	0.7107	3	0.7476	1
Ludhiana	0.7368	2	0.6580	8	0.7053	2
Fatehgarh Sahib	0.7304	3	0.6024	12	0.6792	3
Kapurthala	0.6772	5	0.6056	11	0.6486	4
Patiala	0.5795	9	0.6892	4	0.6234	5
Nawanshahr	0.5931	8	0.6295	10	0.6077	6
Muktsar	0.4369	17	0.8538	1	0.6036	7
Amritsar	0.6340	7	0.5160	17	0.5868	8
Bathinda	0.4457	15	0.7877	2	0.5825	9
SAS Nagar	0.7054	4	0.3643	21	0.5689	10
Moga	0.4588	13	0.6858	5	0.5496	11
Tarn Taran	0.5081	11	0.5584	16	0.5282	12
Faridkot	0.4349	18	0.6651	6	0.5270	13
Barnala	0.4234	20	0.6617	7	0.5187	14
Rupnagar	0.5627	10	0.4090	20	0.5012	15
Fazilka	0.4434	16	0.5792	13	0.4977	16
Sangrur	0.4471	14	0.5647	15	0.4941	17
Firozepur	0.4123	21	0.5768	14	0.4781	18
Hoshiarpur	0.4998	12	0.4379	19	0.4750	19
Pathankot	0.6491	6	0.1707	22	0.4577	20
Gurdaspur	0.4336	19	0.4576	18	0.4432	21
Mansa	0.2775	22	0.6558	9	0.4288	22

Districts wise rank and indices of sustainable food access and its components in Uttar Pradesh

District	Index of Food Access Security		Index of Food Access Sustenance		Sustainable Food Access Index	
	Index value	Rank	Index value	Rank	Index value	Rank
Meerut	0.7602	2	0.6587	10	0.7196	1
Baghpat	0.7703	1	0.5006	56	0.6624	2
Bulandshahr	0.7107	5	0.5897	28	0.6623	3
Muzaffarnagar	0.6602	6	0.6500	11	0.6561	4
Ghaziabad	0.7425	3	0.4933	59	0.6428	5
Mathura	0.6346	8	0.6393	14	0.6365	6
Saharanpur	0.5942	11	0.6780	7	0.6277	7
Gautam Buddha Nagar	0.7123	4	0.4894	61	0.6232	8
Aligarh	0.6377	7	0.5878	30	0.6177	9
Hathras	0.5793	13	0.6442	12	0.6052	10
Agra	0.6282	9	0.5432	42	0.5942	11
Firozabad	0.5829	12	0.5760	33	0.5801	12
Bijnor	0.5065	23	0.6793	6	0.5756	13
Lalitpur	0.5142	18	0.6327	17	0.5616	14
Chandauli	0.4561	32	0.7113	2	0.5582	15
Moradabad	0.5103	20	0.6263	22	0.5567	16
Amroha	0.5690	15	0.4763	66	0.5319	17
Allahabad	0.5292	17	0.5181	53	0.5248	18
Banda	0.4463	35	0.6392	15	0.5235	19
Shamli	0.5710	14	0.4512	69	0.5231	20
Mahoba	0.5085	21	0.5327	46	0.5182	21
Sonbhadra	0.4160	39	0.6701	9	0.5176	22
Hamirpur	0.4358	38	0.6396	13	0.5173	23
Mirzapur	0.3896	46	0.7051	3	0.5158	24
Gorakhpur	0.4587	31	0.5981	26	0.5145	25
Bareilly	0.4456	36	0.6103	23	0.5115	26
Rampur	0.4825	27	0.5539	38	0.5110	27
Sant Ravidas Nagar	0.5081	22	0.5099	54	0.5088	28
Lucknow	0.4673	29	0.5709	34	0.5087	29
Pilibhit	0.3607	59	0.7303	1	0.5085	30
Varanasi	0.5456	16	0.4353	70	0.5015	31
Raebareli	0.3822	50	0.6795	5	0.5011	32
Deoria	0.4890	25	0.4946	58	0.4913	33
Kanpur Nagar	0.4865	26	0.4957	57	0.4902	34
Fatehpur	0.4467	34	0.5498	39	0.4880	35
Ballia	0.3910	45	0.6319	18	0.4873	36
Maharajganj	0.4475	33	0.5455	41	0.4867	37
Chitrakoot	0.4368	37	0.5613	37	0.4866	38
Farukkhabad	0.4113	40	0.5972	27	0.4856	39

Kasganj	0.5140	19	0.4318	71	0.4811	40
Balrampur	0.3742	52	0.6286	20	0.4759	41
Jhansi	0.5042	24	0.4257	73	0.4728	42
Sant Kabir Nagar	0.3568	61	0.6292	19	0.4658	43
Hapur	0.6041	10	0.2488	75	0.4620	44
Barabanki	0.3757	51	0.5887	29	0.4609	45
Sambhal	0.4618	30	0.4588	68	0.4606	46
Sitapur	0.3472	62	0.6272	21	0.4592	47
Gonda	0.3832	48	0.5679	35	0.4571	48
Sultanpur	0.3697	56	0.5858	31	0.4561	49
Kheri	0.3097	70	0.6717	8	0.4545	50
Shahjahanpur	0.2947	71	0.6800	4	0.4489	51
Budaun	0.3978	44	0.5220	51	0.4475	52
Jalaun	0.3890	47	0.5345	45	0.4472	53
Kushi Nagar	0.4078	41	0.5055	55	0.4469	54
Etah	0.4698	28	0.3990	74	0.4415	55
Mau	0.3825	49	0.5219	52	0.4382	56
Basti	0.3741	53	0.5299	47	0.4364	57
Ghazipur	0.3985	43	0.4915	60	0.4357	58
Azamgarh	0.4022	42	0.4776	65	0.4324	59
Jaunpur	0.3711	54	0.5234	50	0.4320	60
Pratapgarh	0.3663	57	0.5282	48	0.4311	61
Ambedkar Nagar	0.3316	65	0.5780	32	0.4302	62
Siddharth Nagar	0.3144	68	0.6005	25	0.4289	63
Auraiya	0.3371	64	0.5637	36	0.4278	64
Shravasti	0.2808	72	0.6356	16	0.4227	65
Mainpuri	0.3232	66	0.5486	40	0.4134	66
Etawah	0.3619	58	0.4880	62	0.4123	67
Faizabad	0.3603	60	0.4878	63	0.4113	68
Unnao	0.3131	69	0.5402	43	0.4039	69
Kanpur Dehat	0.3188	67	0.5276	49	0.4023	70
Kaushambi	0.3443	63	0.4872	64	0.4014	71
Kannauj	0.3702	55	0.4303	72	0.3942	72
Bahraich	0.2450	74	0.6095	24	0.3908	73
Hardoi	0.2392	75	0.5365	44	0.3581	74
Amethi	0.2606	73	0.4746	67	0.3462	75

Districts wise rank and indices of sustainable food security and its components in Punjab

District	Sustainable Food Availability Index		Sustainable Food Access Index		Food Utilization Index		Sustainable Food Security Index	
	Index value	Rank	Index value	Rank	Index value	Rank	Index value	Rank
Ludhiana	0.6359	16	0.7053	2	0.8138	3	0.7110	1
Fatehgarh Sahib	0.7299	6	0.6792	3	0.6496	7	0.6847	2
Amritsar	0.6090	18	0.5868	8	0.7899	4	0.6505	3
Kapurthala	0.7483	3	0.6486	4	0.5538	11	0.6405	4
Hoshiarpur	0.6809	11	0.4750	19	0.9002	1	0.6404	5
Jalandhar	0.5564	19	0.7476	1	0.6353	9	0.6371	6
Nawanshahr	0.7171	7	0.6077	6	0.5279	12	0.6080	7
Gurdaspur	0.6581	12	0.4432	21	0.8236	2	0.6012	8
Patiala	0.6414	15	0.6234	5	0.5177	13	0.5888	9
Tarn Taran	0.6576	14	0.5282	12	0.5744	10	0.5820	10
SAS Nagar	0.4751	22	0.5689	10	0.7699	5	0.5812	11
Rupnagar	0.6194	17	0.5012	15	0.6379	8	0.5795	12
Pathankot	0.5378	21	0.4577	20	0.7238	6	0.5529	13
Faridkot	0.7734	1	0.5270	13	0.3753	15	0.5124	14
Barnala	0.6580	13	0.5187	14	0.4036	14	0.5063	15
Bathinda	0.7322	4	0.5825	9	0.3103	18	0.4758	16
Firozepur	0.6969	9	0.4781	18	0.3236	17	0.4534	17
Sangrur	0.5540	20	0.4941	17	0.3530	16	0.4504	18
Fazilka	0.6959	10	0.4977	16	0.2774	19	0.4255	19
Moga	0.7311	5	0.5496	11	0.1796	20	0.3427	20
Muktsar	0.7730	2	0.6036	7	0.1428	22	0.3014	21
Mansa	0.7002	8	0.4288	22	0.1549	21	0.2936	22

Districts wise rank and indices of sustainable food security and its components in Uttar Pradesh

District	Sustainable Food Availability Index		Sustainable Food Access Index		Food Utilization Index		Sustainable Food Security Index	
	Index value	Rank	Index value	Rank	Index value	Rank	Index value	Rank
Meerut	0.6334	37	0.7196	1	0.7434	7	0.6954	1
Bulandshahr	0.6516	24	0.6623	3	0.6295	23	0.6475	2
Muzaffarnagar	0.6295	38	0.6561	4	0.6435	22	0.6429	3
Hathras	0.6694	12	0.6052	10	0.6524	21	0.6412	4
Saharanpur	0.6052	46	0.6277	7	0.6587	19	0.6298	5
Agra	0.5936	51	0.5942	11	0.7139	9	0.6291	6
Gautam Buddha Nagar	0.5837	52	0.6232	8	0.6715	15	0.6241	7
Deoria	0.6659	13	0.4913	33	0.7840	4	0.6233	8
Aligarh	0.6159	44	0.6177	9	0.6175	27	0.6170	9
Chandauli	0.7217	2	0.5582	15	0.5910	33	0.6161	10
Ballia	0.6490	26	0.4873	36	0.7830	5	0.6160	11
Gorakhpur	0.6413	32	0.5145	25	0.7308	8	0.6158	12
Baghpat	0.5646	58	0.6624	2	0.6199	26	0.6130	13
Firozabad	0.6173	43	0.5801	12	0.6163	28	0.6041	14
Azamgarh	0.6546	20	0.4324	59	0.8632	1	0.6001	15
Ghaziabad	0.4805	72	0.6428	5	0.6968	12	0.5915	16
Bijnor	0.6483	28	0.5756	13	0.5562	38	0.5909	17
Lucknow	0.5203	69	0.5087	29	0.8368	3	0.5902	18
Jalaun	0.5989	48	0.4472	53	0.7749	6	0.5773	19
Mau	0.6546	21	0.4382	56	0.7103	10	0.5750	20
Shamli	0.6362	35	0.5231	20	0.5602	37	0.5694	21
Ghazipur	0.6412	33	0.4357	58	0.6921	13	0.5661	22
Varanasi	0.5303	68	0.5015	31	0.6920	14	0.5634	23
Jhansi	0.5688	55	0.4728	42	0.6659	17	0.5582	24
Hapur	0.6616	16	0.4620	44	0.5809	34	0.5558	25
Jaunpur	0.6199	41	0.4320	60	0.6688	16	0.5532	26
Farrukhabad	0.5655	57	0.4856	39	0.6143	29	0.5499	27
Moradabad	0.6416	31	0.5567	16	0.4727	53	0.5484	28
Ambedkar Nagar	0.6581	18	0.4302	62	0.6027	32	0.5451	29
Kanpur Nagar	0.4327	74	0.4902	34	0.8587	2	0.5439	30
Mathura	0.5982	49	0.6365	6	0.4380	58	0.5429	31
Etah	0.6650	14	0.4415	55	0.5644	36	0.5414	32
Bareilly	0.6736	9	0.5115	26	0.4693	54	0.5386	33
Amroha	0.6529	23	0.5319	17	0.4625	55	0.5383	34
Auraiya	0.5777	53	0.4278	64	0.6598	18	0.5372	35
Mainpuri	0.6539	22	0.4134	66	0.6086	30	0.5365	36

Sant Kabir Nagar	0.6603	17	0.4658	43	0.5176	41	0.5364	37
Kannauj	0.6155	45	0.3942	72	0.6558	20	0.5276	38
Etawah	0.5457	63	0.4123	67	0.6992	11	0.5275	39
Banda	0.5130	70	0.5235	19	0.5433	39	0.5263	40
Faizabad	0.6186	42	0.4113	68	0.6046	31	0.5262	41
Sultanpur	0.6250	40	0.4561	49	0.5215	40	0.5254	42
Allahabad	0.5354	65	0.5248	18	0.5113	44	0.5237	43
Pilibhit	0.7001	6	0.5085	30	0.4258	60	0.5224	44
Sambhal	0.7123	4	0.4606	46	0.4568	56	0.5205	45
Kushi Nagar	0.6732	10	0.4469	54	0.4895	48	0.5203	46
Shahjahanpur	0.6731	11	0.4489	51	0.4830	51	0.5187	47
Gonda	0.6554	19	0.4571	48	0.4810	52	0.5179	48
Bara Banki	0.6404	34	0.4609	45	0.4849	50	0.5178	49
Fatehpur	0.5490	62	0.4880	35	0.5085	46	0.5139	50
Rampur	0.6641	15	0.5110	27	0.4199	62	0.5134	51
Kheri	0.7079	5	0.4545	50	0.4451	57	0.5120	52
Hamirpur	0.4286	75	0.5173	23	0.6211	25	0.5105	53
Basti	0.6049	47	0.4364	57	0.5114	43	0.5085	54
Kasganj	0.7349	1	0.4811	40	0.4034	64	0.5069	55
Raebareli	0.5310	66	0.5011	32	0.4862	49	0.5054	56
Unnao	0.5767	54	0.4039	69	0.5755	35	0.5044	57
Budaun	0.6952	7	0.4475	52	0.4266	59	0.4986	58
Pratapgarh	0.5670	56	0.4311	61	0.5096	45	0.4962	59
Lalitpur	0.6349	36	0.5616	14	0.3716	67	0.4962	60
Kanpur Dehat	0.4995	71	0.4023	70	0.6268	24	0.4932	61
Sitapur	0.6450	29	0.4592	47	0.4214	61	0.4917	62
Mahoba	0.5545	61	0.5182	21	0.3960	65	0.4793	63
Mirzapur	0.5554	59	0.5158	24	0.3903	66	0.4761	64
Hardoi	0.6291	39	0.3581	74	0.5063	47	0.4719	65
Amethi	0.6508	25	0.3462	75	0.5162	42	0.4716	66
Siddharth Nagar	0.6923	8	0.4289	63	0.3639	68	0.4598	67
Chitrakoot	0.4636	73	0.4866	38	0.4132	63	0.4523	68
Sonbhadra	0.5309	67	0.5176	22	0.3530	69	0.4512	69
Maharajganj	0.7183	3	0.4867	37	0.2681	74	0.4180	70
Sant Ravidas Nagar	0.5362	64	0.5088	28	0.2859	71	0.4094	71
Kaushambi	0.5553	60	0.4014	71	0.3201	70	0.4045	72
Balrampur	0.5951	50	0.4759	41	0.2687	73	0.3999	73
Bahraich	0.6487	27	0.3908	73	0.2816	72	0.3921	74
Shravasti	0.6427	30	0.4227	65	0.0677	75	0.1604	75

LIST OF PUBLISHED/ACCEPTED/SUBMITTED RESEARCH ARTICLES

S.No	Title	Journal	NAAS rating	Status
1	Foodgrains productivity and its drivers in Uttar Pradesh: drawing inferences from panel data analysis	Current Science	6.97	Submitted
2	Mapping district wise sustainable food security status in Indian state of Punjab	Agricultural Research	5.90	Submitted
3	Mapping sustainable food security status in gangetic plains of India: evidences from the state of Uttar Pradesh	Outlook on Agriculture	6.44	Submitted

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[csblr] Submission Acknowledgement

2 messages

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Respected Madam,
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Foodgrains productivity and its drivers in Uttar Pradesh: drawing inferences from panel data analysis

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Abstract

Based on past fifteen years (2000/01 to 2016/17) data, the present study ascertained the recent trends and acceleration/deceleration of growth in area, production and productivity of foodgrains in Indian state of Uttar Pradesh. The choice of the study area is guided by its largest share in national foodgrains production. Besides, using district wise panel data for the aforesaid period, the drivers of foodgrains productivity in the state were identified through Least Square Dummy Variable (LSDV) model. Productivity gains in total foodgrains over the time estimated to be the prime factor behind agriculture production growth in the state over the past one and half decade. The crop wise analysis revealed the significant decline in area under nutritive and climate smart crops i.e., pulses and nutri-cereals which calls for prior intervention through crop area substitution for ensuring sustainable agricultural growth in the state. The higher intercept value (1.0895) for western region in the regression estimates signified it as premier productive region of Uttar Pradesh compared to other regions of the state. The findings of the study suggest sincere policy interventions towards crop sequencing, enhancing irrigation efficiency and irrigation coverage in the state for long term productivity gains as both cropping and irrigation intensity estimated to have significant positive effect on yield with elasticity 0.24 and 0.13, respectively. Strengthening rural educational infrastructure for harnessing untapped potential of rural workforce of the state is another important message of the present analysis.

Keywords: Foodgrains productivity, Uttar Pradesh, panel data analysis

Introduction

Agriculture productivity growth has remained subject of intense debate among scientific circle as well as policy circle in India. Large numbers of studies have been taken up across the country for understanding the agricultural growth pattern over the time at national level[1,2]. However, the pattern of agricultural growth and development at regional level for evolving strategic decentralized development strategies to ensure inclusive growth in the country in the long-run have been much stressed in the agricultural economics literature[3,4,5,6].

As states are the appropriate administrative unit to study regional dimensions of agricultural growth and development, the present study has analysed the performances of agriculture in terms of crop wise productivity growth over the time in the state of Uttar Pradesh. The choice of the state is guided by its highest share (around 17 %) in national foodgrains production and thus its obvious importance in national food security. The state economy is predominantly agriculture covering a sizeable part of the highly fertile Upper and Middle Gangetic Plain and engages around 59 per cent of the total workforce[7].

Nonetheless, few studies in recent past on assessing trends in productivity growth have also considered the state of Uttar Pradesh as an important case[8,9,10] as the state engrosses prominent position in the agricultural development of the country, however the study pertaining to the factors determining foodgrains productivity are scant in the state, the information on which is crucial for accelerating agricultural growth with strategic intervention. In an another study on emphasizing productivity growth as crucial factor for rural development and poverty reduction in Uttar Pradesh, Pandey & Reddy[11] though recognized fertilizer and irrigation as important determinants for productivity growth, but ignored social and institutional factors that accentuates productivity growth pattern of a region.

The survey of literature on assessing growth pattern of area, production and productivity of crops revealed that the previous studies assumed linear relation of growth with time[8,12,13,14,15]. As growth is seldom unidirectional, capturing rate of change in the growth rate over the time more clearly depicts instantaneous increment or decline in growth rate of the parameter of our interest[16]. In this backdrop, we have modestly attempted to explore the trends in growth of area, production and productivity of foodgrains in Uttar Pradesh along with their acceleration/deceleration over the time and identified determinants of foodgrains productivity at more disaggregated level for strategic planning and prioritizing allocation of resources for accelerating the productivity growth in the state.

Data and Approach

Data

The study is based on district level panel data collected from various secondary sources for a comprehensive period of 2000/01 to 2016/17. The district wise data pertaining to area under foodgrains (rice, wheat, nutri cereals, total cereals and pulses) and their production, gross cropped area, net sown area, area under irrigation were sourced from website of the Directorate of Economics and Statistics, Ministry of Agriculture and Farmer's Welfare. The information on number of agricultural labours and rural literacy rate was gathered from Population Census conducted every 10 years. The data regarding number of small and marginal farmers and agricultural credit were obtained from the agricultural census conducted on quinquennial basis. For inter-census periods, linear interpolation technique was used to fill the data gaps. The mean kharif and rabi rainfall for each district were sourced from India Meteorological Department (IMD), Pune at a spatial resolution of 0.25 ×0.25 degree. Data on district wise fertilizer (NPK) consumption, number of tractors and length of road were compiled from the Statistical Abstracts

of Uttar Pradesh, Directorate of Economics and Statistics, Government of Uttar Pradesh for the different years. Since the changes in district boundaries poses challenges in preparing uniform district level panel data set, district boundary adjustment was done for partitioned districts considering the year 2016-17 as base following Choudhary[17]. The districts carved out from two or more districts were adjusted by providing population weights that permits easy construction of panels[18,19,20].

Statistical Analysis

Growth performance of agriculture

The compound annual growth rate of area, production and productivity of crops over a comprehensive period of TE2000/01 - TE2016/17 and for the two sub periods PI and PII viz., TE2000/01-2010/11 and TE 2010/11-2016/17, respectively as well as acceleration and deceleration in its growth rates were estimated using the following log-quadratic model[21]:

$$\ln Y_{it} = a + bt + ct^2 + u_t \quad \text{.....(i)}$$

Where,

Y_{it} = Area / production / productivity of i^{th} crop in 't' time period

i = Paddy, Wheat, Nutri cereals, Total cereals, Pulses, Total foodgrains

t = TE2000/01-2010/11, TE2010/11-2016/17, TE2000/01-2016/17

Estimated value of *b* and *c* gives the measure of growth rate and acceleration or deceleration, respectively. If *c* is significantly positive it indicates acceleration, significant negative value shows deceleration in growth rate and insignificant value implies stagnation in growth process[22]. The inclusion of time squared term on the right hand side of equation (i) gave rise the problem of multicollinearity. This is avoided by the normalization of time in mean deviation form, that is, by

setting t = 0 at the midpoint of the series and this allows the time (t) and its square (t^2) to become orthogonal[21].

Determinants of foodgrains productivity

The drivers of foodgrains productivity were identified through panel data modeling approach. Foodgrains productivity as dependent variable was regressed with twelve different socio-economic and climatic factors utlilizing panel for time period, 2000-2016.

$$\ln (FG\_Y)_{it} = \beta_0 + \beta_1 \ln (FERT)_{it} + \beta_2 \ln (CI)_{it} + \beta_3 \ln (IRRI)_{it} + \beta_4 \ln (TW)_{it} + \beta_5 \ln(AL)_{it} + \beta_6 \ln (TRAC)_{it} + \beta_7 \ln (RD)_{it} + \beta_8 \ln (KR)_{it} + \beta_9 \ln (RR)_{it} + \beta_{10} \ln (RL)_{it} + \beta_{11} \ln (SMF)_{it} + \beta_{12} \ln (AC)_{it} + \beta_{13} D1 + \beta_{14} D2 + \beta_{15} D3 + \varepsilon \quad \text{.....(ii)}$$

Where, FG_Y indicates foodgrains yield (qtl/ha), FERT implies fertilizer use per hectare of gross cropped area (kg/ha), CI is cropping intensity (%), IRRI is gross cropped area under irrigation (%), TW shows contribution of tubewell as source of irrigation (%), AL indicate agricultural labour use per unit of gross cropped area (no./ha), TRAC depicts number of tractors per hectare of gross cropped area (no./ha), RD is road density (length per Sq Km), KR and RR are the average kharif and rabi rainfall (mm), respectively. RL describes rural literacy (%), SMF is the number of small and marginal holding farmers (no.), AC shows the agricultural credit disbursed by commercial banks per unit of gross cropped area (Rs/ha). i and t represents district and year respectively, i = 1, 2,…..,75 ; t= 2000,2001, …., 2016.

The panel data estimation technique involves fixed and random effect model; however choice of the model is guided by Hausman test[23]. The fixed effects assume that the individual specific effect is correlated to the regressors while random effects assume that individual specific effects are uncorrelated with the regressors. Both fixed and random effects model were attempted and based on the Hausman test, fixed effect model was selected (Annexure I).

Given the large size of the state and its diverse geography and climatic conditions, Uttar Pradesh is divided into 4 economic regions – Western, Central, Eastern and Bundelkhand[24] (Annexure II). Therefore, to take into account the individuality of each region/ cross-sectional unit, intercept is varied by using dummy variable for fixed effects. The model is popularly known as Least Square Duumy Variable (LSDV) model[25]. Dummy for Bundelkhand region is used as comparison. D1, D2 and D3 are dummies for Central region, Eastern region, Western region, respectively.

β_1, β_2 ..... B_{15} are the output elasticities of the respective input variables. For the ease of interpretation and policy prescription, the above regression model was estimated as double log function. The analysis has been carried out using Stata/SE.

Results and Discussion

Growth in area, production and productivity of foodgrains

The performance of agriculture in the state over the time has been analysed in terms of growth in area, production and productivity of foodgrains. The average area, production and yield of foodgrains and its various crop components viz., paddy, wheat, nutri-cereals, total cereals and pulses during the overall period TE2000/01 to TE2016/17 and two sub-periods TE2000/01-2010/11 (PI) and TE2010/11-2016/17 (PII) have been presented in table 1. During the overall period, foodgrains production increased significantly in the state at an accelerated rate with CAGR 0.824 per cent. This growth was mainly attributed to the increase in the productivity of foodgrains, since the area remain stagnated during the same time period. It is noteworthy here that in the sub period I foodgrains area declined significantly accompanied by acceleration in its growth rate (Table 2).

The production of total cereals during the overall period increased at an accelerated rate and the growth was absolutely yield driven since area under the same has not increased significantly during the same time period. Similar pattern have been observed in the growth performance of paddy which is the major cereal crop of the state. The two drought years i.e., the agricultural year of 2002-03 and 2009-10, lead accelerated decline in production and yield of paddy during the period I. It is interesting to note that the production growth of wheat in Uttar Pradesh during the last 15 years have been primarily area driven as productivity of the crop has remained stagnated. The striking increase of average area under wheat by 5 million hectare in PII from the previous period is also evident from Table1. The productivity growth of nutri-cereals has been quite robust (CAGR 2.05%) during the overall period despite of the significant decline in area under the crops during the same period (Table 2). The share of pulses in area and production of total foodgrains in the state hovered around 12 per cent and 4 per cent, respectively during the overall period under consideration (Table 1). The growth in the production of pulses also revealed dismal trend in the state during the entire study period. The production of pulses in the state declined significantly at an annual rate of 1.50 per cent during the overall time period and was mainly attributed to the significant decline in area (CAGR 1.35%) during the same period, though the area declined with decelerated rate. The period wise analysis showed that area, production and productivity of pulses was on declining trend during both the sub periods, though the decline was significant during the decadal period of TE 2000/01 to TE2009/10.

Determinants of foodgrains productivity

Based on the district wise average foodgrains productivity for the year 2000-2016, the districts in each region of the state have been delineated into three categories namely high (23.50-32.27 qtl/ha), medium (14-23.49 qtl/ha) and low (8.34-14.15 qtl/ha) using k means clustering

approach[26]. The table 3 indicates that most of the districts in the western region are highly productive while more than three quarter of the districts lying in the eastern region has productivity below 14 qtl/ha.

The descriptive statistics of the variables used in the model are summarized in Table 4. The data set tested negative for the problem of heteroscedasticity and multicollineraity. The estimated result of the LSDV model with two way fixed effect i.e., cross sectional and period, are presented in Table 5. Cross sectional fixed effects are assumed to absorb the unobserved district-specific time-invariant variable that influence foodgrains yield and minimise estimation bias due to omitted variables. Period fixed effects control for annual differences in productivity within the cross section, which might have arisen due to changes in technology, infrastructure and other omitted variables.

The estimated regression equation has the expected sign of the coefficients with around 73 percent of the goodness of fit and large number of them is significant. The importance of fertilizer in enhancing the productivity of crops has been unanimously reported[27,28]. Interestingly, this variable has significant effect in increasing the yield of foodgrains in the present study. Likewise, cropping intensity is also yield enhancing in its effect with elasticity of 0.23. Along with the fertilizers, irrigation and its sources (tubewells) as well as mechanization have emerged to be the critical factor in determining the foodgrains productivity in the state. These factors help in raising the cropping intensity through timeliness and better quality of operations and precision in the application of the inputs[29, 30]. In concordance with the a-priori expectations, irrigation, tubewell irrigation and use of tractors all have positive and significant effect on foodgrains yield. On the contrary, the estimated elasticity of agricultural labour on productivity is -0.043.

Agriculture in India is still highly dependent on monsoon rainfall, thus the importance of rainfall in augmenting the agricultural crop production does not need much emphasis[31,32]. It is noteworthy to mention that while *kharif* rainfall has significant yield triggering effect; rainfall in the rabi season adversely affect foodgrains productivity. Rural literacy which shows the quality of human resources found to improve the foodgrains yield significantly. Emphasizing its importance in agriculture, Mittal & Kumar[33], Meitei & Devi[34] and Choudhary[17] in their study opined that literacy plays critical role in enhancing human capabilities for adopting modern agricultural technologies, thus increases productivity gains.

The relationship between farm size and productivity has been a debatable issue. Few previous studies at national level[35,36,37] have provided convincing evidences on positive relationship between marginal holdings and crop productivity; however the relation varies across states[38] and with food commodity groups[39]. The findings of the present study suggests that with unit percentage increase in the number of small and marginal holdings, the productivity of foodgrains declines significantly by 0.037 per cent. The results of NSSO 2003 farmers' survey establish that in state of Uttar Pradesh, Madhya Pradesh, Himachal Pradesh, Kerala and Tamil Nadu, large farms have higher productivity (in value terms) than marginal farmers. As availability of agricultural credit catalyzes the usage of modern inputs [40,41]; its significant effect on foodgrains productivity (Table 5) is obvious.

The table 6 represents the intercept values for different economic regions of the state accounting the individuality of each cross sectional unit. Nevertheless, dummies for all the regions have positive and significant relationship with foodgrains yield (Table 5), the higher intercept value (1.0895) of western part of the state represents highest land productivity of the region. The western region which lies in Upper Gangetic Plains of India endowed with higher water table

and has more conducive climatic conditions for growing crops than other parts of the state (Srivastava, 2006).

Summary and Conclusions

In Uttar Pradesh, the performance of agriculture measured in terms of foodgrains production and yield varies considerably over the time and across the regions. The growth in production of total foodgrains over the past one and half decade is mainly productivity led growth, since the area under the same was stagnated during the same period. The crop wise analysis shows significant increase in the production of paddy and wheat owing to their significant increase in the productivity and area, respectively during the overall study period. It is noteworthy that the stagnant yield growth of wheat in the state would pose serious challenges in meeting the future availability need of the major staple crop at national level as well. Hence, research and development breakthrough for genetic advancement to enhance the yield potential of wheat crop would be desirable policy intervention in this direction.

Further, in spite of the accelerated and significant growth in productivity of nutri cereals during the overall period 2000/01-2016/17, there has been no significant increase in production due to marked decline in its area during the same period. The decline in production of pulses in the state is mainly attributed to shrinkage of area under the crop. This decline in area under nutri-cereals and pulses over the time signals the inclination of farmers towards rice-wheat mono-cropping. The diversification of food plate of consumers towards nutrition rich diets calls for crop area substitution with nutri cereals and pulses. Therefore, the state government should intervene for augmenting area under these climate smart crops through strengthening the marketing and price support policies.

The analysis has revealed the crucial role of cropping intensity, irrigation and rural literacy in enhancing the foodgrains productivity. The unit percentage increase in cropping intensity increases the foodgrains yield by 0.24 per cent. Since the cropland area is difficult to increase therefore intensifying the land use is the only option. In this direction, crop sequencing and supplementing the crop intensification with proper water and nutrient management would be more policy imperative in long run. Another important message from this study is that interventions towards increasing the irrigation coverage under the crops will be critical to enhance productivity gains. About 80 per cent of the available water is used in agriculture in India, yet more than half of the cropped area remains rainfed. However, if rainwater were properly harvested, conserved and utilized; an additional 25-30 per cent of the area can be provided with irrigation[43]. Hence investment to create on-farm structures for harvesting, storage and distribution of water and to promote micro irrigation techniques such as drip and sprinkler system of irrigation in the state would be important policy prescription. The findings of the study further accentuates critical role of rural literacy in enhancing the productivity of foodgrains. Therefore, the state government has to play a major role in strengthening rural educational infrastructure for harnessing untapped potential of rural workforce. Mainstreaming practically oriented, participatory and interactive model like farmer field school (FFS) program, to educate the farmers about modern farm practices, and strong extension services should be the prior policy thrust of the government to boost the foodgrains productivity in the state.

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Table 1: Mean and standard deviations of crop production parameters

Crops	TE 2000/01 to TE2009/10			TE 2010/11 to TE2016/17			TE2000/01 to TE2016/17		
	A	P	Y	A	P	Y	A	P	Y
Paddy	58.25 (1.22)	117.19 (5.06)	20.10 (0.66)	59.20 (0.98)	134.94 (7.61)	22.78 (1.03)	58.64 (1.19)	124.50 (10.82)	21.20 (1.58)
Wheat	93.57 (1.15)	252.70 (12.72)	27.14 (0.93)	97.93 (0.41)	287.10 (24.00)	29.35 (2.46)	95.37 (2.39)	266.87 (24.73)	28.05 (2.00)
Nutri cereals	22.59 (1.85)	32.19 (2.12)	14.28 (0.48)	20.03 (0.11)	34.96 (2.37)	17.45 (1.15)	21.54 (1.90)	33.33 (2.57)	15.59 (1.79)
Total cereals	172.08 (3.50)	398.08 (16.17)	23.12 (0.75)	176.08 (2.64)	452.57 (19.00)	25.71 (1.08)	173.73 (3.69)	420.51 (32.35)	24.18 (1.58)
Pulses	26.12 (1.54)	21.25 (1.99)	8.13 (0.42)	23.45 (1.01)	19.97 (2.88)	8.48 (1.02)	25.02 (1.88)	20.72 (2.40)	8.27 (0.72)
Foodgrains	198.50 (4.19)	420.25 (15.61)	21.17 (0.75)	198.87 (1.63)	467.53 (24.47)	23.50 (1.14)	198.65 (3.30)	439.72 (30.61)	22.13 (1.48)

Note: Figures in parentheses shows standard deviation

A – area (million hectare), P – production (million tonnes), Y – productivity (qtl/ha)

Table 2: Area, production and yield dynamics of crops and total foodgrains in Uttar Pradesh

Periods	Area		Production		Yield	
	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration	Growth rate	Acceleration/ Deceleration
Paddy						
TE 2000/01 to TE2009/10	-0.107 (-0.44)	0.277 (1.58)	-0.163 (-0.32)	0.860** (3.19)	-0.035 (-0.09)	0.585** (2.45)
TE 2010/11 to TE2016/17	0.695* (4.78)	-0.187 (-1.15)	1.547 (1.62)	-2.234** (-4.37)	0.857 (1.00)	-2.056* (-5.16)
TE2000/01 to TE2016/17	0.166 (1.74)	0.011** (2.37)	1.278* (4.44)	0.075* (5.60)	1.122* (4.70)	0.064* (5.55)
Wheat						
TE 2000/01 to TE2009/10	0.344* (4.67)	0.125** (3.13)	1.218** (3.15)	0.458 (1.66)	0.562 (1.65)	0.578** (3.11)
TE 2010/11 to TE2016/17	0.112 (1.58)	-0.127 (-1.93)	-2.868** (-2.42)	-2.231** (-2.22)	-2.919** (-2.50)	-2.125 (-1.99)
TE2000/01 to TE2016/17	0.469* (11.32)	0.025* (9.42)	1.128* (3.16)	0.052** (2.47)	0.561 (1.74)	0.024 (1.31)
Nutri Cereals						
TE 2000/01 to TE2009/10	-2.521* (-9.17)	0.353 (1.86)	-1.761* (-4.29)	0.594 (2.25)	0.758** (2.65)	0.269 (1.23)
TE 2010/11 to TE2016/17	-0.017 (-0.15)	-0.230 (-2.71)	2.719** (3.50)	-1.867* (-5.10)	2.732** (3.93)	-1.649* (-4.65)
TE2000/01 to TE2016/17	-1.516* (-8.32)	-0.071* (-5.03)	0.536 (1.47)	0.043** (2.43)	2.047* (9.29)	0.115* (12.97)
Total Cereals						
TE 2000/01 to TE2009/10	-0.420 (-2.29)	0.352* (4.49)	0.124 (0.26)	0.873* (3.90)	0.547 (1.69)	0.530** (2.88)
TE 2010/11 to TE2016/17	0.626* (4.59)	-0.293** (-3.03)	-0.382 (-0.45)	-1.911** (-3.64)	-0.984 (-1.31)	-1.621** (-3.07)
TE2000/01 to TE2016/17	0.156 (1.55)	0.012** (2.50)	1.099* (4.12)	0.061* (4.32)	0.951* (4.36)	0.048* (3.92)
Pulses						
TE 2000/01 to TE2009/10	-1.583* (-3.54)	-0.823* (-3.86)	-3.045* (-10.62)	-0.409 (-2.20)	-1.444* (-4.82)	0.434 (2.25)
TE 2010/11 to TE2016/17	-1.727** (-3.70)	-0.479 (-0.87)	-4.467 (-1.90)	-5.358** (-3.76)	-3.015 (-1.41)	-5.009** (4.32)
TE2000/01 to TE2016/17	-1.354* (-8.06)	-0.072* (-7.64)	-1.498* (-3.11)	-0.079* (-3.00)	-0.183 (-0.42)	-0.009 (-0.40)
Foodgrains						
TE 2000/01 to TE2009/10	-0.601* (-5.02)	0.198** (2.92)	-0.068 (-0.15)	0.795* (3.79)	0.539 (1.49)	0.604** (3.01)
TE 2010/11 to TE2016/17	0.184 (1.23)	-0.350** (-4.49)	-1.052 (-1.08)	-2.092** (-3.04)	-1.230 (-1.47)	-1.749** (-2.78)
TE2000/01 to TE2016/17	-0.091 (-1.13)	0.002 (-0.36)	0.824** (2.96)	0.044* (3.01)	0.918* (3.83)	0.046* (3.43)

Note: *Significant @ 1%, ** significant @ 5 % level of significance
Figures in parentheses shows two-tailed t-statistics

Table 3: Regional distribution of districts across productivity levels

Region	High (23.50-32.27 qtl/ha)	Medium (14.16-23.49 qtl/ha)	Low (8.34-14.15 qtl/ha)	Total
Bundelkhand region	0	6	1	7
Central region	4	6	0	10
Eastern region	4	2	20	26
Western region	25	7	0	32
Overall	33	21	21	75

Table 4: Descriptive statistics for selected drivers of foodgrains productivity

Variables	Bundelkhand region	Central region	Eastern region	Western region	Overall
Foodgrains yield					
Mean	12.5	22.59	21.42	27.64	23.40
SD	4.10	4.32	3.90	4.66	6.18
Fertilizer use					
Mean	68.9	157.83	158.70	174.82	157.15
SD	40.54	59.77	63.97	57.51	65.79
Cropping intensity					
Mean	128.96	152.81	156.00	159.78	154.64
SD	19.38	16.64	13.10	14.45	17.13
Irrigation					
Mean	42.77	78.9	70.1	88.49	76.57
SD	11.10	8.57	20.82	18.18	22.23
Tubewells					
Mean	28.13	73.99	71.67	74.01	68.92
SD	22.68	13.55	26.11	18.15	24.90
Agricultural labour					
Mean	0.26	0.39	0.39	0.34	0.35
SD	0.12	0.14	0.13	0.17	0.15
Tractor					
Mean	29.66	31.23	30.98	48.56	38.37
SD	12.65	13.38	11.89	31.15	24.04
Road density					
Mean	0.37	0.63	0.84	0.74	0.72
SD	0.11	0.25	0.37	0.51	0.42
Kharif rainfall					
Mean	594.65	636.22	666.73	527.91	596.67
SD	298.06	331.61	374.78	300.10	337.07
Rabi rainfall					
Mean	65.26	70.63	73.46	59.17	67.35
SD	31.39	29.68	37.83	27.36	33.87
Rural literacy					
Mean	62.49	62.21	61.11	63.26	62.29
SD	11.21	11.38	13.09	12.24	12.35
Small & Marginal farmers					
Mean	168122.30	400203.40	354698.50	212939.50	282751.00
SD	36322.39	134194.60	137326.90	101551.30	142675.40
Agricultural credit					
Mean	6861.98	8193.68	11826.43	30119.05	18667.89
SD	16304.99	17179.99	45663.76	72625.73	55965.10

Table 5: Regression estimates of LSDV model

Dependent Variable: **Log (Foodgrains yield)**		
Method: **Least Square Dummy Variable Model**		
Effect Specification: **Cross Sectional and Period Fixed Effect**		
Variables	**Co-efficient**	**t-ratio**
Constant	0.5376**	2.12
Fertilizer	0.0347**	2.30
Cropping intensity	0.2367*	4.39
Irrigation	0.1278*	5.32
Tubewell	0.0589*	9.01
Agricultural labour	-0.0436*	-2.82
Tractor	0.0991*	8.22
Road density	- 0.0036	-0.24
Kharif rainfall	0.0665*	7.29
Rabi rainfall	-0.0022	0.97
Rural literacy	0.1593*	4.50
Small and Marginal farmers	-0.0377*	-3.11
Agricultural credit	.0079**	2.40
Central region	0.4528*	15.99
Eastern region	0.4156*	15.28
Western region	0.5519*	20.59
R^2	0.7283*	
Total panel (balanced) observations	1275	

*Significant @ 1%, ** significant @ 5 % level of significance

Table 6: Regional intercept value (Fixed Effect)

Economic Regions	**Intercept value**
Bundelkhand region	0.5376
Central region	0.9904
Eastern region	0.9532
Western region	1.0895

Annexures

Annexure I: Hausman Fixed and Random effect coefficients

Coefficient	Fixed	Random	Difference	Standard Error
Fertilizer use	0.0421	0.0232	0.0189	0.0018
Cropping Intensity	-0.0264	0.3600	-0.3864	0.0491
Irrigation	0.1236	0.2915	-0.1678	0.0222
Tubewell	-0.0275	0.0221	-0.0497	0.0095
Agricultural labour	-0.0025	0.0184	-0.0209	0.0113
Tractor	-0.0180	0.1354	-0.1534	0.0364
Road density	0.0627	0.1274	-0.0647	0.0124
Kharif rainfall	0.1079	0.0983	0.0096	0.0006
Rabi rainfall	0.0345	0.0203	0.0142	0.0012
Rural literacy	-0.0594	-0.0194	-0.0400	0.0176
Small & Marginal farmers	2.3357	-0.0375	2.3732	0.3373
Agricultural credit	-0.0111	-0.0034	-0.0077	0.0013
Chi^2 value	129.55*			

*Significant @ 1%, ** significant @ 5 % level of significance

Annexure II: Economic region of Uttar Pradesh

S.No.	Region	Districts
1.	Western	Agra, Mainpuri, Firozabad, Aligarh, Kasganj, Bareilly, Badaun, Bulandshar, Etah, Etawah, Farrukhabad, Mathura, Meerut, Ghaziabad, Muradabad, Pilibhit, Rampur, Muzaffarnagar, Saharanpur, Bijnor, Shahjahanpur, Baghpat, Gautam Buddha Nagar, Hathras, Amroha, Kannauj, Auriya
2.	Central	Bara Banki, Fatehpur, Hardoi, Kanpur Nagar, Kanpur Dehat, Kheri, Lucknow, Raebareli, Sitapur, Unnao
3.	Eastern	Allahabad, Kaushambi, Azamgarh, Mau, Ballia, Bahraich, Basti. Siddharth Nagar, Deoria, Faizabad, Ghazipur, Gonda, Gorakhpur, Maharajganj, Jaunpur, Mirzapur, Sonbhadra, Pratapgarh, Sultanpur, Varanasi, Balrampur, Shravasti, Chandauli, Sant Ravidas Nagar, Kushi Nagar, Sant Kabir Nagar, Ambedkar Nagar
4.	Bundelkhand	Jhansi, Jalaun, Hamirpur, Mohaba, Banda, Chtirakoot, Lalitpur

Source: Government of Uttar Pradesh, 2009

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Mapping district wise sustainable food security status in Indian state of Punjab

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Abstract

With the manifestation of stagnating or declining productivity levels and the emergence of environmental externalities, the concerns for sustainability of food security in Indian state of Punjab has emerged in recent past. Following the indexing approach, the present paper construct the district level sustainable food security index to identify the specific dimensions that require prior policy attention for ensuring food security for the future generations. Principal Component Analysis (PCA) technique was used to assign weights to indicators of each dimension of food security. The sustainability of food security increased as one moves from southern to northern parts of the state. Districts in the western (Fazilka, Muktsar etc.) and southern (Mansa and Sangrur) part of Malwa region of the state were rated low in sustainable food security index. The study establishes that improving food access and utilization capacity are more critical than food availability for ensuring sustainable food security in the state.

Key words: Sustainability of food security, Punjab, principal component analysis, food access

Introduction

The glorious journey of Punjab in achieving national self sufficiency in terms of food production and minimizing the fluctuations is well documented [3; 10]; however the notion of environmental sustainability has increasingly occupied centre stage in agricultural development policy of the state. The cropping pattern dominated by wheat-rice rotation is causing a serious damage to the state's natural resource base [9; 7; 13]. Nevertheless, Punjab has been ranked as food secure region in India [22]; with the manifestation of stagnating or declining productivity levels and the emergence of environmental externalities, the concerns for sustainability of food security in the state has emerged in recent past.

The review of vast literature on assessing food security status indicates that in a large number of studies, current availability of food has been accorded prime place for ensuring food security [1; 12]. The sustainability of food availability which is crucial for ensuring the food security of future generation has been largely ignored. Without integrating sustainability as an explicit dimension of food security, today's policies and programmes could become the very cause of increased food insecurity in the future [2].To feed the growing population, food is being produced at the cost of critical natural resources as evidenced by degradation of soil, lowering of water tables, clearing of forests [15; 16] and thus it poses a threat for the security of future.

Before designing and implementing the policy interventions to maintain/enhance the sustainability of a system, it is imperative to have improved understanding on essential conditions for sustainable development in a given region. The major approaches used in the previous studies to assess the sustainability of a system in a particular region include computation of composite indices covering varied dimensions of sustainability [4; 17; 18; 5] and Response-Inducing Sustainability Evaluation (RISE) [11]. Nonetheless, both the techniques has its own utility; the index based approach is more simple practical tool for indicating a set of interventions required to address the problem areas that impede sustainability.

In this backdrop, the present paper, following the indexing approach, construct the Sustainable Food Security Index to characterize the districts in Punjab according to their relative sustainability status in terms of food security and to identify the specific dimensions that require prior policy attention for orientation of development programmes for ensuring food security for the future generations.

Data and Approach

Data

Taking cue from an atlas of the sustainability of food security developed by [22], composite index of food security has been constructed from its components – food availability, access and utilization to assess the food security as well as its sustainability at district level in the state of Punjab for the year 2015-16.

Development of sustainable food security index

Selection of indicators

Since sustainability of food security has been the focus of study therefore the indicators for food availability and access were divided into two sets – one set of indicators deals with present security and other with future sustenance while for food utilization, only present security has been taken into consideration. On the basis of availability and reliability of data, a total of twenty nine indicators were selected from wide range of indicators used in previous standard studies and grouped as indicators of sustainable food availability (13), sustainability of food access (12) and food absorption (4). Table 1 gives the glimpses of indicators, their relation with each component of food security i.e., availability, access and utilization as well as its respective sources.

Table 1: Indicators and their functional relationship with sustainable food security

Component	Related with	Indicators	Relation with sustainable food security	Source
Food Availability	**Present security**	Cropping Intensity (%)	Direct	Directorate of Economics and Statistics, Ministry of Agriculture and Farmer's Welfare, Government of India
		Change in net sown area (%)	Direct	
		Food grain production per capita (kgs/month/ person)	Direct	
		Irrigation Intensity (%)	Direct	
		Fertilizer consumption (NPK) (Tonnes/ha)	Direct	Fertilizer Association of India
		Population density (Person/km^2)	Inverse	Population census
		Milk Productivity (MT/milch animal/year)	Direct	Estimated from 19^{th} Livestock Census
	Future sustenance	Per capita forest cover (Hectare)	Direct	Directorate of Economics and Statistics, Ministry of Agriculture and Farmer's Welfare, Government of India
		Leguminous crops in gross cropped area (%)	Direct	

		Degraded area to geographical area (%)	Inverse	
		Unexploited ground water for future (Hectare metre)	Direct	Central Ground Water Board, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India
		Growth rate of annual mean temperature (%)	Inverse	India Meteorological Department (IMD), Pune
		Coefficient of variation of monthly mean rainfall (%)	Inverse	
Food Access	**Present security**	Below poverty line population (%)	Inverse	Statistical Abstract of Punjab
		Non agricultural workers to total workers (%)	Direct	Population census
		Non worker population (%)	Inverse	
		Number of milch animals per 000' population (No.)	Direct	19th Livestock census
		Cross bred adoption rate (%)	Direct	
		Buffalo : Indigenous Cattle ratio (%)	Direct	
		Small and marginal farmers per 000' population (No.)	Inverse	Agricultural census
	Future sustenance	Average size of holding (Hectare)	Direct	Agricultural census
		Livestock density (No./km^2)	Inverse	Estimated from 19th Livestock Census data
		Non crop agricultural workers (%)	Direct	Economic Census
		Landless labour households to total households (%)	Direct	Socio-Economic & Caste census
		Instability in cereal production (%)	Inverse	Estimated from data sourced from Directorate of Economics and Statistics, Ministry of Agriculture and Farmer's Welfare, Government of India
Food Utilization	**Present security**	Safe drinking water (%)	Direct	Estimated from Census of India data
		Infant mortality rate (%)	Inverse	
		Health infrastructure (No.)	Direct	
		Female literacy rate (%)	Direct	

2.2.2 Normalization of indicators

As the indicators were measured in different units and scale, so they were normalized into standard unit using min-max technique [20]. This permits the value of indicators to lie between 0 and 1 which has direct effect on the composite indicators.

$$I_{ijk} = \frac{X_{ijk} - Min\ X_{ijk}}{Max\ X_{ijk} - Min\ X_{ijk}}$$ …… (1) when indicator has +ve association with the component

$$I_{ijk} = \frac{Max\ X_{ijk} - X_{ijk}}{Max\ X_{ijk} - Min\ X_{ijk}}$$ ….. (2) when indicator has -ve association with the component

where,

X_{ijk} = value of i^{th} indicator representing j^{th} component of Sustainable Food Security Index of k^{th} district.

2.2.3 Assigning weights to indicators and construction of Sustainable Food Security Index

Based on the past reviewed literature [8; 14; 23; 19; 6] the 'Principal Component Analysis (PCA)' is supposed to be the most reliable method for assigning weights to the indicators while constructing food security index. PCA is a multivariate statistical technique helps to compress the data by reducing the number of dimension without much loss of information and thus creates a new set of variables out of a given set of variables (Xj , i=1, 2, 3, …., k) called principal components (Pi), which are linear components of Xj and can be represented as:

$$P_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \ldots\ldots + a_{1k}X_k$$
$$P_2 = a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + \ldots\ldots + a_{2k}X_k$$
$$\vdots$$
$$P_k = a_{k1}X_1 + a_{k2}X_2 + a_{k3}X_3 + \ldots\ldots + a_{kk}X_k \quad \ldots\ldots\ldots\ldots\ldots (3)$$

where a_s are loadings chosen such that the first principal component explains the maximum possible variation in all Xj . The first principal component accounts for the maximum possible proportion of the variance of the set of variables followed by the second principal component, and so on. In this paper, the first component is used as a weight since it captures the maximum variance of all the components.

Following the above procedure separate indices for each component of sustainable food security viz., Index of food availability security (FAI), Index of food availability sustenance (FSI), Index of food access security (FASI), Index of food access sustenance (FASUI) and Index of food utilization (FUI) has been constructed. The composite Sustainable Food Availability Index (SFAI) and Sustainable Food Access Index (SFAcI) was computed as the weighted mean of their respective components as:

$$SFAI = FAI*0.55 + FSI*0.45 \quad \ldots\ldots\ldots\ldots\ldots (4)$$

$$SFAcI = FASI*0.60 + FASUI*0.40 \quad \ldots\ldots\ldots\ldots (5)$$

where the weights (0.55, 0.45, 0.60, 0.40) has been assigned depending on their share in total indicators considered for the respective composite index [22].

Finally the Sustainable Food Security Index (SFSI) for each district (k) was calculated as weighted mean of the three composite indices viz., Sustainable Food Availability Index (SFAI), Sustainable Food Access Index (SFAcI) and Food Utilization Index (FUI).

$$SFSI_k = \frac{(W_1 * SFAI_k) + (W_2 * SFAcI_k) + (W_3 * FUI_k)}{\sum_{i=1}^{3} W_i} \quad \ldots\ldots\ldots (6)$$

where W_i is the weights apportioned to respective components of SFSI, since SFSI is composite in nature and the relative magnitude of its components varies across regions. W_i is calculated as the ratio of inverse of the proportional contribution of SFAI, SFAcI and FUI to the sum of all the three inverse proportions for the three components for each region and for each component across the regions [5] and thus gives more weight to weaker components in a region rather than equal weights. Higher value of SFSI indicated higher security as well as

sustainability of the region.

Results and Discussion

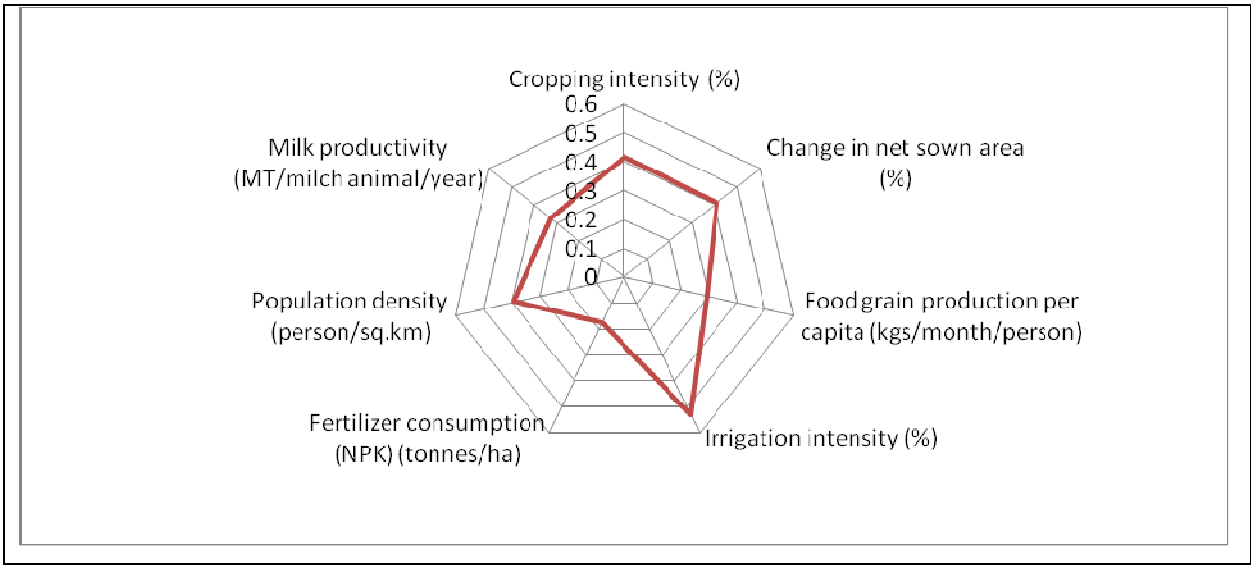
The analysis of food security and its sustainability status assists in identifying the districts/regions which are more secure as well as sustained in terms of food security along with the factors accounting for this security and sustainability. The discussion on the indices of the components of sustainable food security precedes the results of sustainable food security index of the study area.

Sustainable food availability index

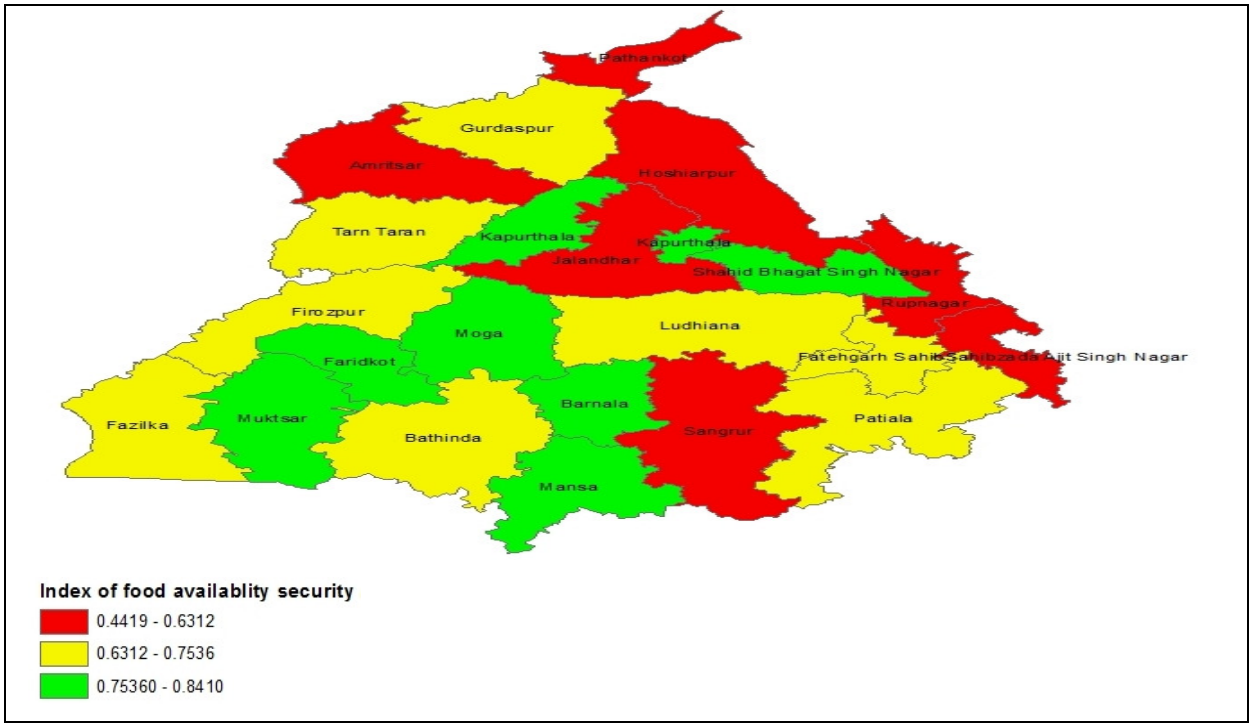
The index was constructed by combining its two sub–indices i.e., Index of food availability security (FAI) and Index of food availability sustenance (FSI). Therefore, the following subsections present detail discussion on sub-indices for the study area which has been delineated into three economic regions viz., Majha, Malwa and Doaba region (Annexure I).

Index of food availability security: The sub-index was computed using total of seven indicators which were cropping intensity, change in net sown area, food grain production per capita, irrigation intensity, fertilizer consumption, population density and milk productivity. The weights were assigned to each indicator using the first principal component which explained around 90 per cent variation in the state (Annexure II). The figure 1 shows the importance of indicators responsible for the security of food availability which is reflected from their weights obtained from principal component analysis. As revealed by the value of weights, irrigation intensity was the most important factor contributing to the security of food availability. The other indicators which influenced the security of food availability were cropping intensity and change in net sown area. Few districts lying in the Malwa region like Moga, Muktsar etc. were highly secured in terms of food availability; however the districts which stood lower in terms of security of food availability were spread in all the three regions viz., Majha (Amritsar and Pathankot), Doaba (Jalandhar) and Malwa (SAS Nagar, Sangrur and Roopnagar) (Map 1). The lowest cropping intensity in SAS Nagar (136.79%) and maximum decrease in the net sown area in Pathankot (by around 36 per cent) was probably the main reason behind less secured status of these districts in terms of food availability in the state of Punjab.

Fig 1: Weights for the indicators of food availability security



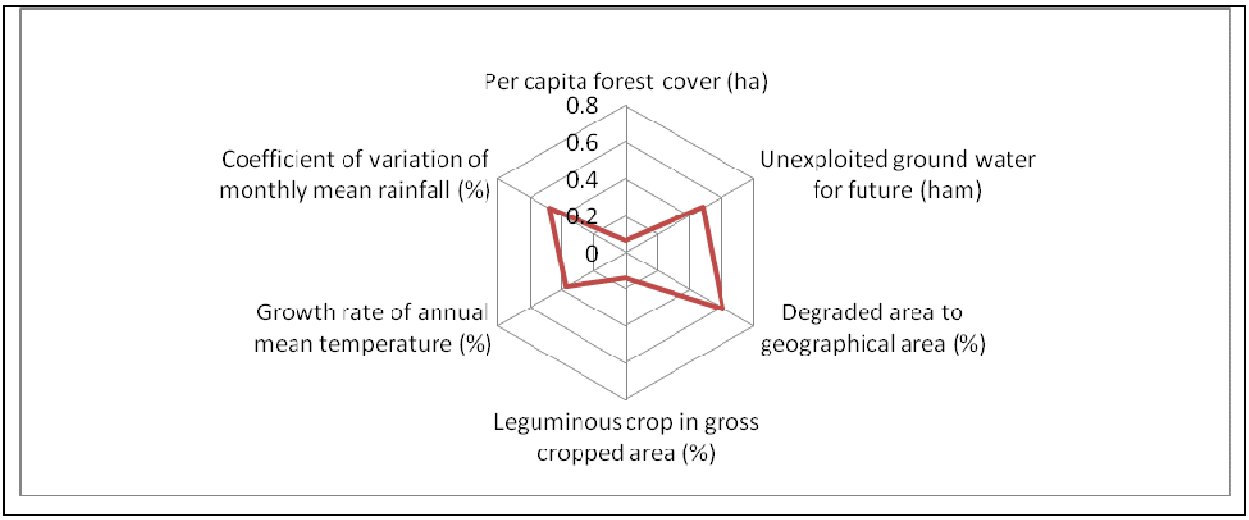
Map 1: District wise food availability security map



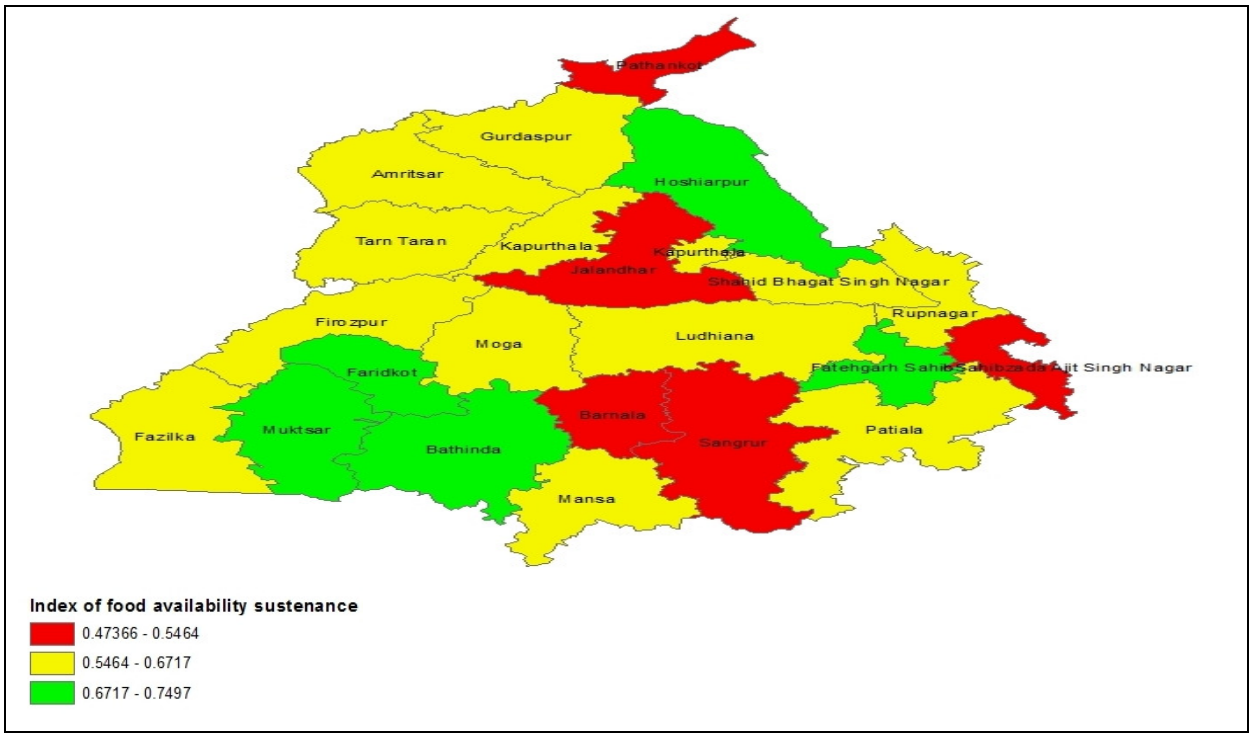
Index of food availability sustenance: The sustenance index of food availability in Punjab varied from a low level of 0.473 in Barnala to the highest level of 0.749 in Hoshiarpur. The first principal component explained about 83 per cent variation and the weights obtained for each indicator from principal component analysis (PCA) is given in figure 2. Proportion of degraded area to geographical area emerged to be the most important indicator. Unexploited groundwater for future use as well as coefficient of variation of monthly mean rainfall also affected the sustenance of food availability in the region. Interestingly, the climatic parameters, the consideration of which has been completely neglected in earlier literatures in constructing index at national and regional level [22] gained importance in influencing the sustenance of food availability in the present study area. Map 2 shows that most of districts in the state lying in the moderate range (0.5464-0.6717) of index of food availability sustenance; however few districts of Malwa region viz., Bhatinda, Faridkot, Muktsar etc. were observed to be highly sustained in terms of food availability. Since the percentage of degraded land to geographical area and unexploited groundwater for future use were the prime indicators and thus was determining the status of food availability sustenance of the districts of Punjab. Districts like Barnala and SAS Nagar have highest percentage of degraded land while in Sangrur and Jalandhar groundwater has been exploited to its maximum extent and therefore the above mentioned districts stood low in terms of food availability sustenance.

As discussed in the methodology section, based on the two indices viz., index of food availability security and index of food availability sustenance, a composite sustainable food availability index has been prepared. The district wise index value along with their ranking is given in Annexure- III. Most of the districts lying in the western part of the Malwa region (Moga, Mansa, Bhatinda, Fazilka etc.) occupied relatively higher rank in sustainable food availability index than that of the other parts of the Punjab (Map 3). As the districts of Jalandhar, Pathankot, Sangrur and SAS Nagar were rated low in security as well as sustenance of food availability, they also stood lower in sustainable food availability.

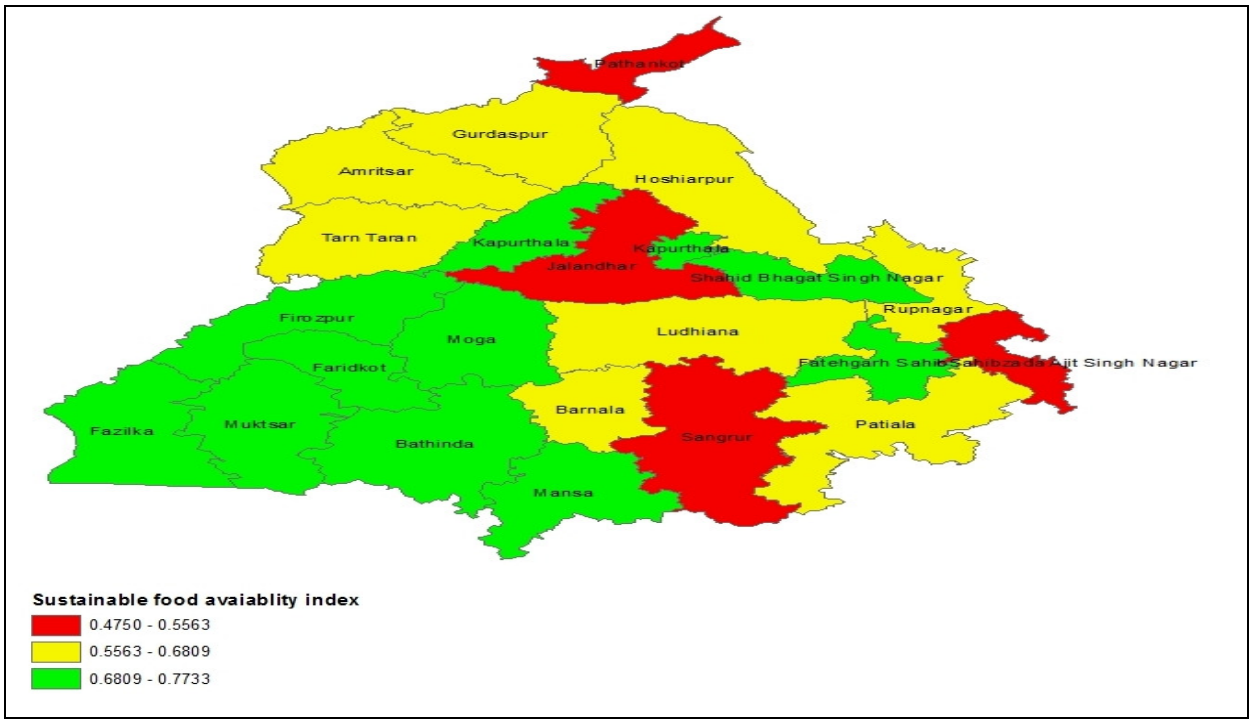
Fig. 2 Weights for the indicators of food availability sustenance



Map 2: District wise food availability sustenance map



Map 3: District wise sustainable food availability map



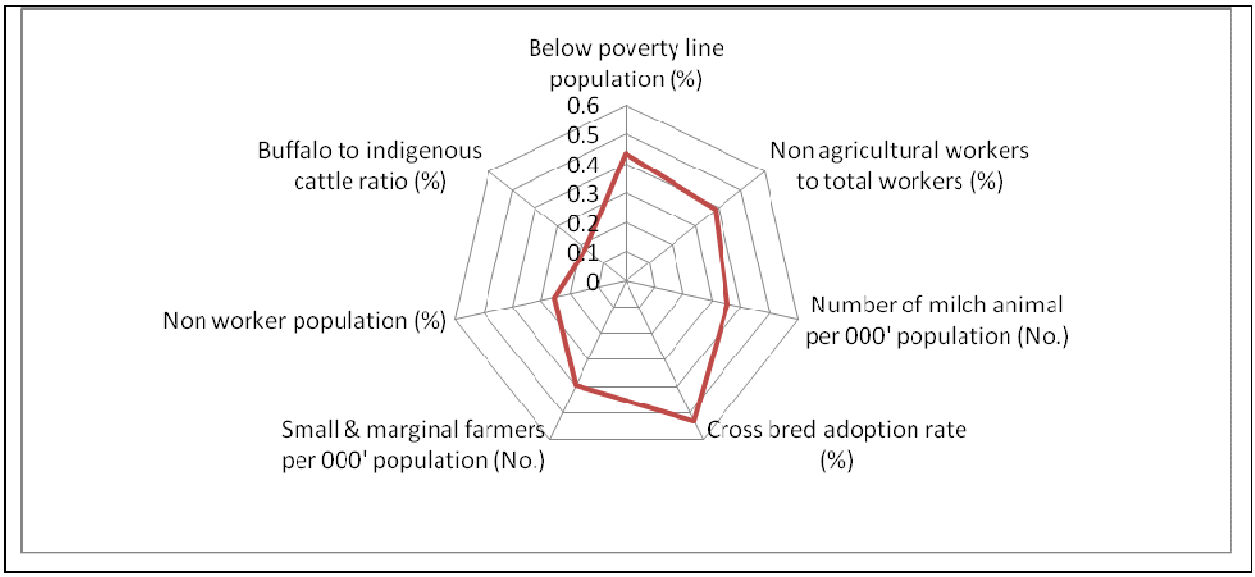
Sustainable food access index

The index has been prepared from the two sub-indices i.e., index of food access security and index of food access sustenance. The following subsections present detail discussion on sub-indices for the study area.

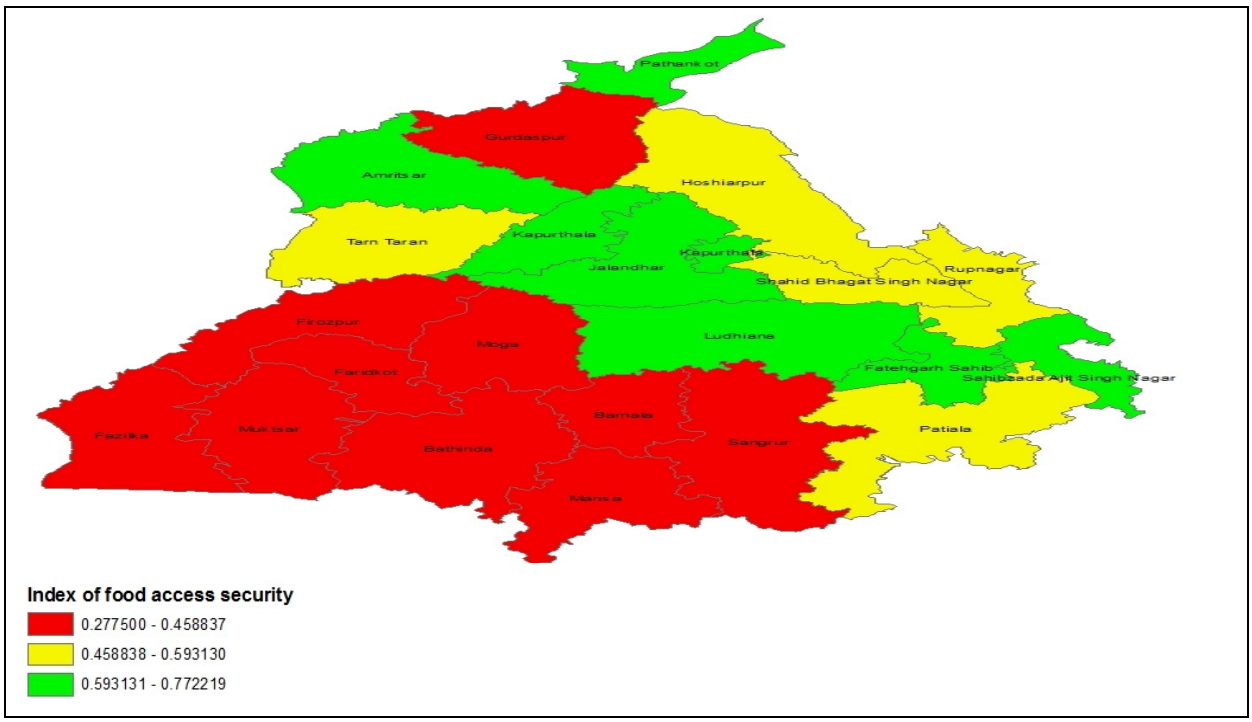
Index of food access security: Weights obtained by PCA revealed that cross bred adoption rate as the most important indicator of food access security (Fig. 3). The other indicators of high influence on food access security were below poverty line population, percentage of non agricultural workers and number of small and marginal farmers. Most of the districts in the Malwa region of Punjab were ranked lower in food access security (Map 4); among which Mansa district occupied the lowest rank owing to the very low percentage of crossbred in total cattle population. The relatively higher rates of poverty and lower percentage of non agricultural workers in districts of Malwa region also added more to lower security of food access. The districts in the Majha region were either moderately or highly secured except Gurdaspur owing to higher number of population below poverty line, relatively higher number of small and marginal as well as non worker population in the district.

Index of food access sustenance: The first principal component explained about 90 per cent variation and the weighs obtained for each indicator from principal component analysis (PCA) is given in Figure 4. The results revealed that the three indicators namely livestock density, percentage of landless labour households and instability in cereal production were the top three indicators. The districts in the northern part of Majha and Doaba region and two districts in eastern part of Malwa region (Rupnagar and SAS Nagar) were occupied lower position in the index of food access sustenance whereas the districts in the southern and central Malwa region were relatively higher sustained in terms of food access (Map 5). The probable reason for lower sustenance of the districts were the larger number of livestock population, smaller percentage of landless labour households and higher instability in the cereal production; also smaller size of average holding added to lower sustenance in the regions.

Fig. 3 Weights for the indicators of food access security

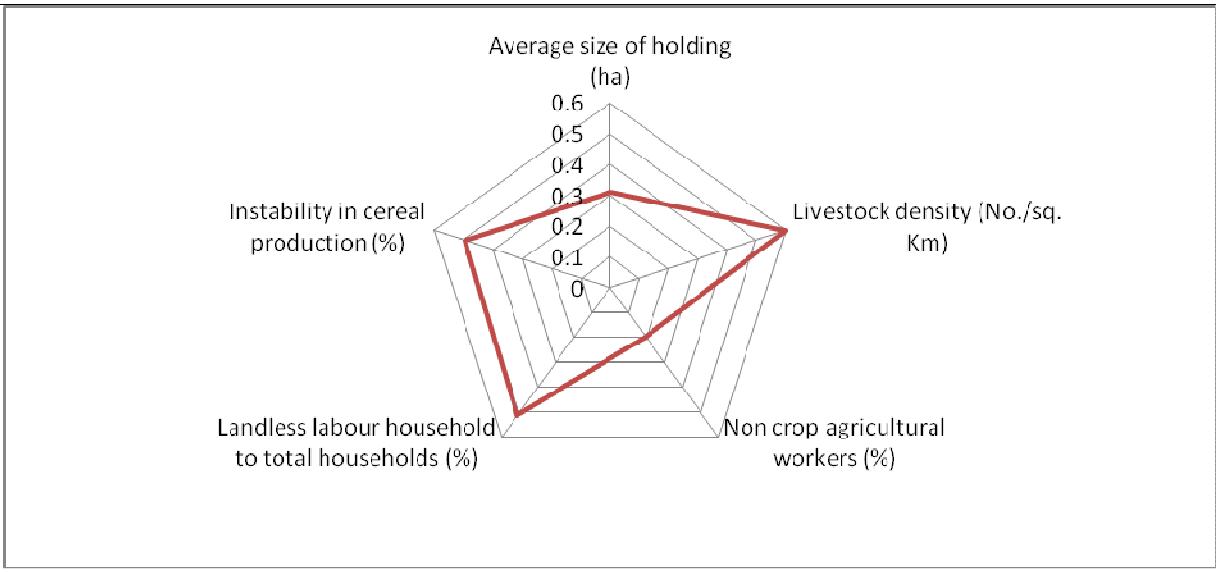


Map 4: District wise food access security map

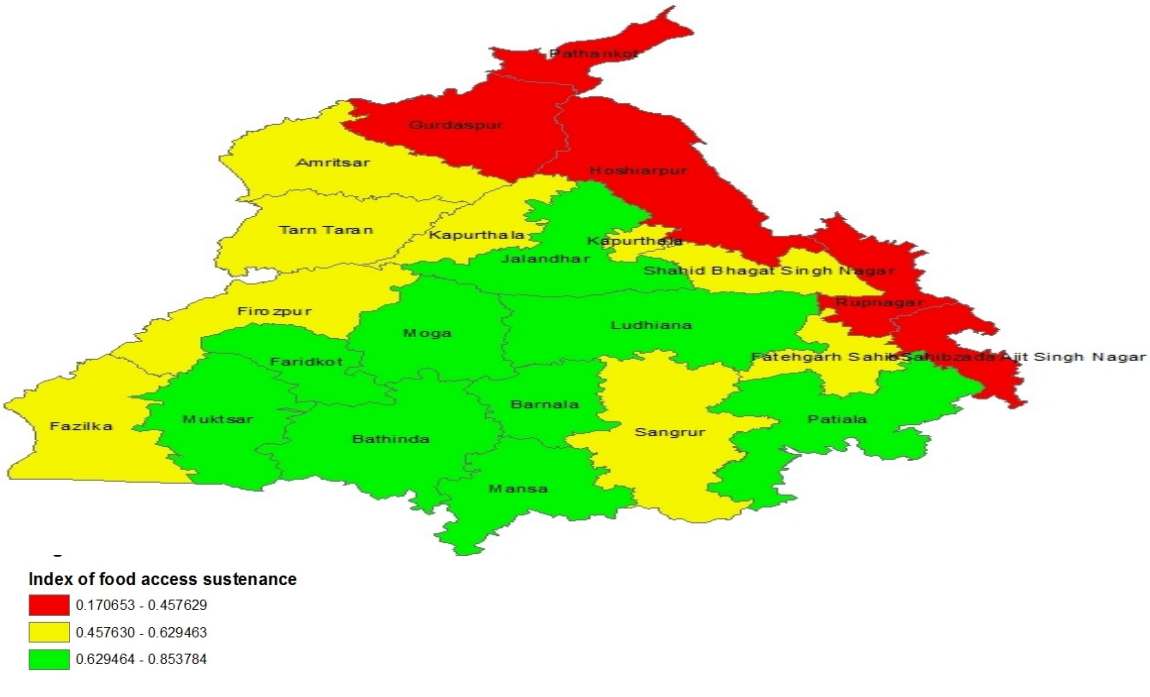


The district wise value of sustainable food access index and their corresponding ranking is given in Annexure III. As the districts of Jalandhar and Ludhiana occupied relatively higher rank in food access security as well as sustenance indices, their sustainable food access index value were also higher (Map 6). Besides, Kapurthala and Fatehgarh Sahib were also rated higher in terms of sustainable food access. Rest of the districts fell into the moderate (0.5283-0.6233) and low (0.4288-0.5282) range of sustainable food access index.

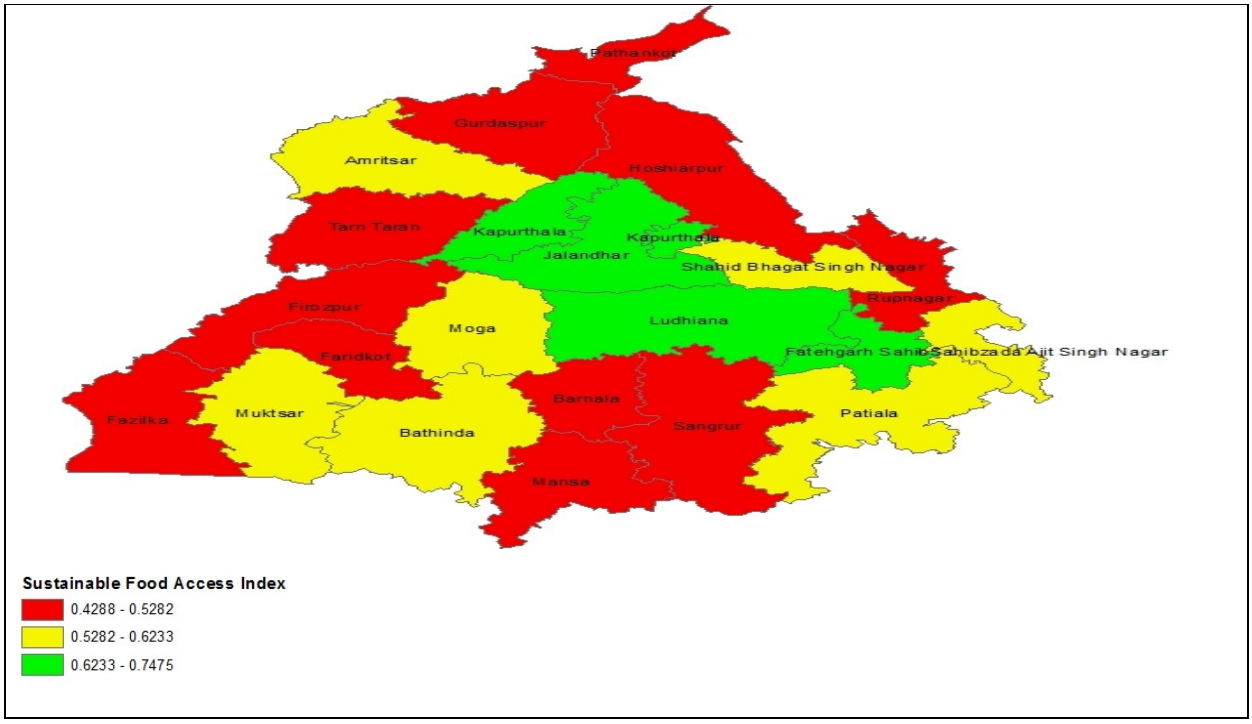
Fig. 4 Weights for the indicators of food access sustenance



Map 5: District wise food access sustenance map



Map 6: District wise sustainable food access map



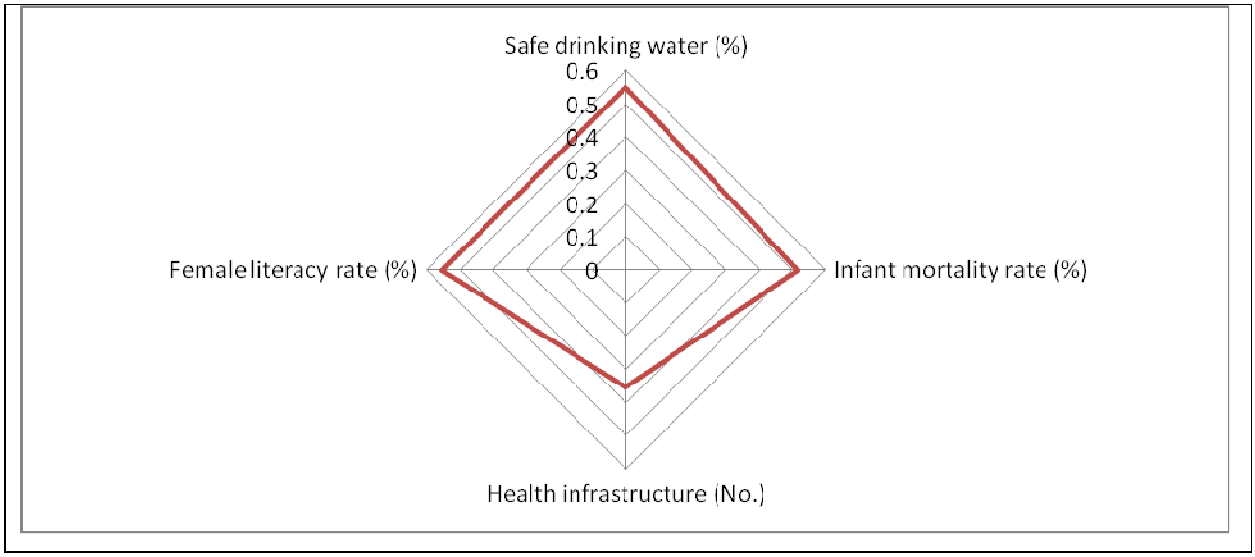
Food utilization index

The index was prepared using a total of four indicators viz., percentage access to safe drinking water, infant mortality rate, female literacy rate and availability of health infrastructure. First principal component explained around 90 per cent variation (Annexure II) and weights obtained by PCA showed that access to safe drinking water and female literacy rate were equally important factors for utilization of food. The next important indicator was infant mortality rate (Fig.5) with weight 0.5160. The availability of health infrastructure got lowest weight in the state. Almost all the districts in the western (Fazilka, Muktsar, Faridkot etc.) and some of the districts in the southern (Sangrur, Mansa etc.) part of Malwa region of Punjab were ranked lower in food utilization index owing to the poor female literacy rate in the region. The importance of literacy rate in determining food utilization was also highlighted by [22] in their study on food security at national level. The poor access of safe drinking water in these regions also added to their lower index value of food utilization (Map 7).

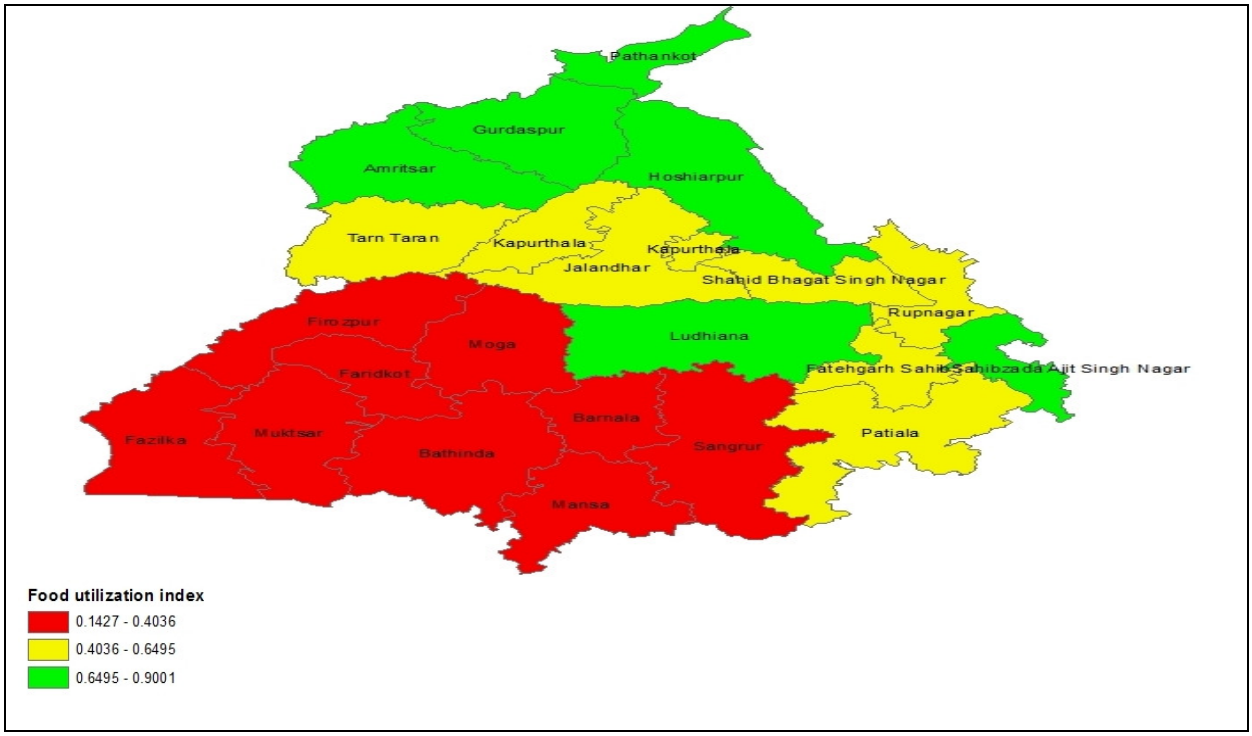
Sustainable food security index

The sustainable food security index was estimated as weighted mean of the three composite indices viz., Sustainable Food Availability Index (SFAI), Sustainable Food Access Index (SFAcI) and Food Utilization Index (FUI). The district wise index values along with their ranking are given in Annexure III. The sustainability of food security increased as one moves from southern to northern parts of the state. Most of the districts in Majha (Amritsar and Gurdaspur) and Doaba (Kapurthala, Hoshiarpur, Jalandhar and SBS Nagar) were ranked high in terms of sustainable food security whereas the districts in the western (Fazilka, Muktsar etc.) and southern (Mansa and Sangrur) part of Malwa region were rated low in sustainable food security index (Map 8).

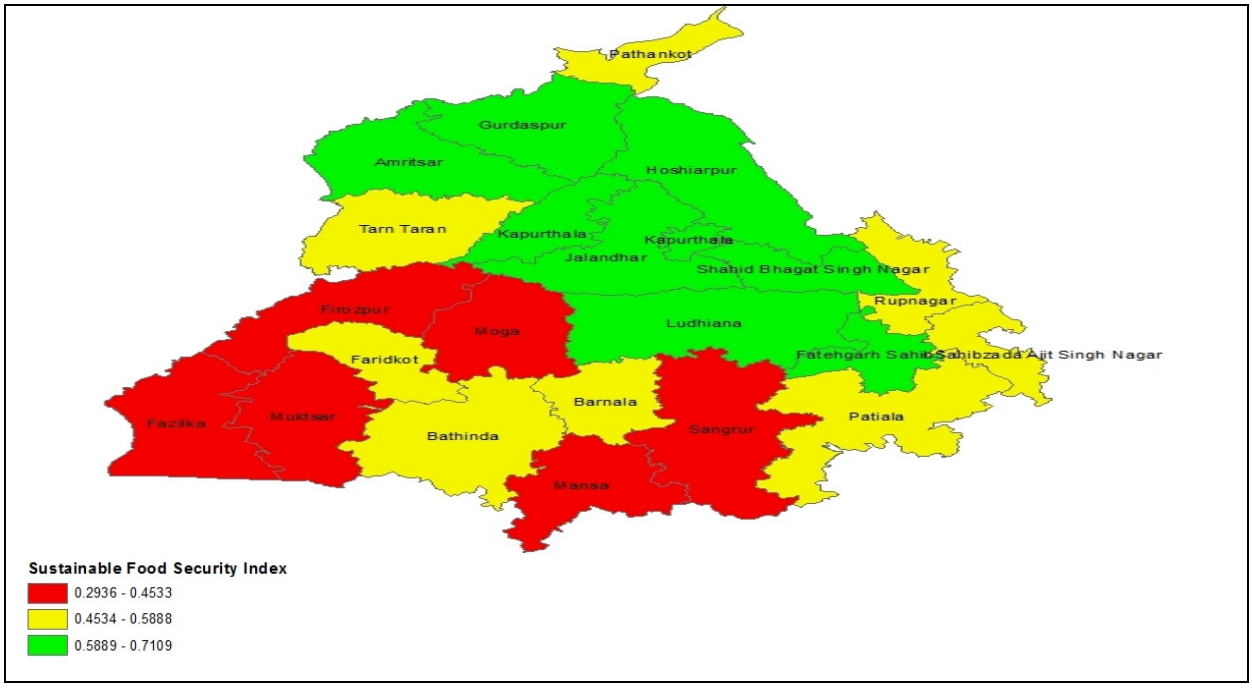
Fig. 5 Weights for the indicators of food utilization



Map 7: District wise food utilization map



Map 8: District wise sustainable food security map



Numbers of districts in different sustainable food security class of the study area has been presented in Table 2. In the state, 28 per cent of the districts were observed to be less sustainable in food security.

Table 2: Number of districts in different sustainable food security class in Punjab

Region	Total districts	Sustainable Food Security Class		
		High	Moderate	Low
Punjab	22	8 (36)	8 (36)	6 (28)

Note: Figures in parentheses are per cent of districts in different sustainable food security class

Table 3: Relative status of components of sustainable food security in low sustainable food secure districts

Study area	Sustainable food security level	Districts	Sustainable food availability level	Sustainable food access level	Food utilization level
Punjab	Low	Firozepur	High	Low	Low
		Sangrur	Low	Low	Low
		Fazilka	High	Low	Low
		Moga	High	Moderate	Low
		Muktsar	High	Moderate	Low
		Mansa	High	Low	Low

Relative status of sustainable food availability, sustainable food access and food utilization level of low sustainable food secure districts (Table 3) revealed that the districts like Firozepur, Sangrur, Fazilka and Mansa were less sustainable in terms of food security owing to the low sustainable food access as well as low utilization level. However, few districts in the state (Moga, Muktasar) were having moderate access to food but have very poor utilization that pushes them in low sustainable food security class. Further, the high rating of the districts in terms of sustainable food availability didn't helped much in pulling them from low sustainable food security status. Therefore the districts experiencing low food access with low or poor food utilization should be targeted areas and must be taken on priority for improving the sustainable food security status of the respective area.

Summary and Conclusion

The findings of the study have several implications for policy makers and scientific community for delineation of policy interventions for ensuring sustainable food security in the most populous and productive agriculture ecosystem in India. As a policy tool it helps in identifying the districts which requires greater policy attention and specifically focuses on critical areas for formulating the district level plans. The findings of the study brought out that the degraded land in Punjab (particularly Malwa region) are looming threat for sustenance of food availability in the state, hence strict land use strategy and efficient watershed management practices should be the top policy priority for reclaiming degraded lands. As the injudicious use of the ground water resources has also emerged as crucial factor that challenges sustenance of food availability in Punjab; strategies for optimizing its use is recommended to taken up at priority basis. Optimal crop mix plans with pulses and nutri cereals will go a long way to arrest the exploitation of ground water resources in the state. Alternate wetting and drying, adoption of System of Rice Intensification (SRI), use of tensiometres and direct plantation of paddy are some of the other widely suggested measures for efficient use of ground water. Promoting crossbred adoption and providing off-farm employment opportunities in Malwa region of Punjab; and endorsing farmers coalition vis. a vis. strategic interventions for minimizing instability in production system in northern Majha and Doaba region of the state should be prior policy options towards ensuring sustainable food access. Besides, in the regions which are rated low in terms of food utilization in the study area, all stakeholders should enact measures to improve female literacy rate and access of safe drinking water for ensuring overall sustainable food security of the study regions. As the study establishes that improving food access and utilization capacity are more critical than food availability for ensuring sustainable food security of the study area, thus it will help the decision makers at all level of decision making in targeting the districts where appropriate measures are to be taken up for strengthening the food access and utilization capacity of people.

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Annexures

Annexure I: Economic Region of Punjab

S.No.	Region	Districts
1.	Majha	Amritsar, Gurdaspur, Pathankot and Tarn Taran
2.	Malwa	Barnala, Bathinda, Fatehgarh Sahib, Faridkot, Fazilka, Firozpur, Ludhiana, Mansa, Moga, SAS Nagar (Mohali), Muktsar, Patiala, Rupnagar and Sangrur
3.	Doaba	Jalandhar, Kapurthala,Hoshiarpur and SBS Nagar (Nawanshahr)

Source: Government of Punjab, 2016

Annexure II: First principal component of different dimensions of sustainable food security

Dimensions of sustainable food security	Punjab	
	Eigen value	Proportion
Food availability security	70.00	0.9045
Food availability sustenance	40.32	0.8329
Food access security	43.41	0.8266
Food access sustenance	35.53	0.8999
Food utilization	27.61	0.8986

Annexure III

Districts wise rank and indices of sustainable food availability and its components in Punjab

District	Index of Food Availability Security		Index of Food Availability Sustenance		Sustainable Food Availability Index	
	Index value	Rank	Index value	Rank	Index value	Rank
Faridkot	0.8068	5	0.7326	2	0.7734	1
Muktsar	0.8288	2	0.7047	5	0.7730	2
Kapurthala	0.8109	3	0.6718	6	0.7483	3
Bathinda	0.7373	10	0.7260	3	0.7322	4
Moga	0.8410	1	0.5968	16	0.7311	5
Fatehgarh Sahib	0.7457	9	0.7107	4	0.7299	6
Nawanshahr	0.7733	7	0.6483	9	0.7171	7
Mansa	0.7764	6	0.6071	15	0.7002	8
Firozepur	0.7536	8	0.6275	12	0.6969	9

Fazilka	0.7191	11	0.6677	7	0.6959	10
Hoshiarpur	0.6246	16	0.7497	1	0.6809	11
Gurdaspur	0.6658	14	0.6486	8	0.6581	12
Barnala	0.8089	4	0.4737	22	0.6580	13
Tarn Taran	0.6889	13	0.6194	14	0.6576	14
Patiala	0.6929	12	0.5786	17	0.6414	15
Ludhiana	0.6313	15	0.6415	10	0.6359	16
Rupnagar	0.6027	17	0.6398	11	0.6194	17
Amritsar	0.5983	18	0.6221	13	0.6090	18
Jalandhar	0.5644	20	0.5465	18	0.5564	19
Sangrur	0.5727	19	0.5311	19	0.5540	20
Pathankot	0.5574	21	0.5138	21	0.5378	21
SAS Nagar	0.4419	22	0.5155	20	0.4751	22

Districts wise rank and indices of sustainable food access and its components in Punjab

District	**Index of Food Access Security**		**Index of Food Access Sustenance**		**Sustainable Food Access Index**	
	Index value	**Rank**	**Index value**	**Rank**	**Index value**	**Rank**
Jalandhar	0.7722	1	0.7107	3	0.7476	1
Ludhiana	0.7368	2	0.6580	8	0.7053	2
Fatehgarh Sahib	0.7304	3	0.6024	12	0.6792	3
Kapurthala	0.6772	5	0.6056	11	0.6486	4
Patiala	0.5795	9	0.6892	4	0.6234	5
Nawanshahr	0.5931	8	0.6295	10	0.6077	6
Muktsar	0.4369	17	0.8538	1	0.6036	7
Amritsar	0.6340	7	0.5160	17	0.5868	8
Bathinda	0.4457	15	0.7877	2	0.5825	9
SAS Nagar	0.7054	4	0.3643	21	0.5689	10
Moga	0.4588	13	0.6858	5	0.5496	11
Tarn Taran	0.5081	11	0.5584	16	0.5282	12
Faridkot	0.4349	18	0.6651	6	0.5270	13
Barnala	0.4234	20	0.6617	7	0.5187	14
Rupnagar	0.5627	10	0.4090	20	0.5012	15
Fazilka	0.4434	16	0.5792	13	0.4977	16
Sangrur	0.4471	14	0.5647	15	0.4941	17
Firozepur	0.4123	21	0.5768	14	0.4781	18
Hoshiarpur	0.4998	12	0.4379	19	0.4750	19
Pathankot	0.6491	6	0.1707	22	0.4577	20
Gurdaspur	0.4336	19	0.4576	18	0.4432	21
Mansa	0.2775	22	0.6558	9	0.4288	22

Districts wise rank and indices of sustainable food security and its components in Punjab

District	Sustainable Food Availability Index		Sustainable Food Access Index		Food Utilization Index		Sustainable Food Security Index	
	Index value	Rank	Index value	Rank	Index value	Rank	Index value	Rank
Ludhiana	0.6359	16	0.7053	2	0.8138	3	0.7110	1
Fatehgarh Sahib	0.7299	6	0.6792	3	0.6496	7	0.6847	2
Amritsar	0.6090	18	0.5868	8	0.7899	4	0.6505	3
Kapurthala	0.7483	3	0.6486	4	0.5538	11	0.6405	4
Hoshiarpur	0.6809	11	0.4750	19	0.9002	1	0.6404	5
Jalandhar	0.5564	19	0.7476	1	0.6353	9	0.6371	6
Nawanshahr	0.7171	7	0.6077	6	0.5279	12	0.6080	7
Gurdaspur	0.6581	12	0.4432	21	0.8236	2	0.6012	8
Patiala	0.6414	15	0.6234	5	0.5177	13	0.5888	9
Tarn Taran	0.6576	14	0.5282	12	0.5744	10	0.5820	10
SAS Nagar	0.4751	22	0.5689	10	0.7699	5	0.5812	11
Rupnagar	0.6194	17	0.5012	15	0.6379	8	0.5795	12
Pathankot	0.5378	21	0.4577	20	0.7238	6	0.5529	13
Faridkot	0.7734	1	0.5270	13	0.3753	15	0.5124	14
Barnala	0.6580	13	0.5187	14	0.4036	14	0.5063	15
Bathinda	0.7322	4	0.5825	9	0.3103	18	0.4758	16
Firozepur	0.6969	9	0.4781	18	0.3236	17	0.4534	17
Sangrur	0.5540	20	0.4941	17	0.3530	16	0.4504	18
Fazilka	0.6959	10	0.4977	16	0.2774	19	0.4255	19
Moga	0.7311	5	0.5496	11	0.1796	20	0.3427	20
Muktsar	0.7730	2	0.6036	7	0.1428	22	0.3014	21
Mansa	0.7002	8	0.4288	22	0.1549	21	0.2936	22

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Mapping sustainable food security status in gangetic plains of India: evidences from the state of Uttar Pradesh

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Abstract

Following the indexing approach, the present paper construct the district level sustainable food security index for Uttar Pradesh to characterize the districts in the state according to their relative sustainability status in terms of food security and to identify the specific dimensions that require prior policy attention for ensuring food security for the future generations. Principal Component Analysis (PCA) technique was used to assign weights to indicators of each dimension of food security. Districts lying in extreme Western (Saharanpur, Baghpat, Meerut etc.) and Eastern (Ballia, Deoria, Mau etc.) parts of the state were highly sustainable in terms of overall food security while a large number of district fell into the moderate range of sustainable food security index. The study establishes that improving food access and utilization capacity are more critical than food availability for ensuring sustainable food security in the state.

Key words: Sustainability of food security, Uttar Pradesh, principal component analysis, food access

1. Introduction

Food security has been the central theme of agricultural development policy in India ever since mid-1960s. The glorious journey of the nation in achieving self sufficiency in terms of food production and minimizing the fluctuations is well documented, however a large chunk of population in the country have been reported to face chronic food insecurity [1]. Nevertheless, the country has witnessed impressive economic growth in the recent years, all its accomplishments plummet down when one look into the widespread poverty and hunger situation. India is home to 14.5 per cent of hungry and malnourished population [2] and in the recently released Global Hunger Index (GHI) report, 2018; the country has been ranked at 103

out of 119 qualifying nations and falls under *serious* category reflecting the severity of food insecurity in India [3]. However, in the studies of national interest, states have shown wide variation in relative food security status within the country. While Punjab, Himachal Pradesh and Kerala emerged as most food secure states [4], the state of Bihar, Uttar Pradesh, Madhya Pradesh and Odisha ranked low in terms of food security status in majority of the studies in Indian context [4, 5]

The review of vast literature on assessing food security status indicates that in a large number of studies, current availability of food has been accorded prime place for ensuring food security [6, 7]. The sustainability of food availability which is crucial for ensuring the food security of future generation has been largely ignored. Without integrating sustainability as an explicit dimension of food security, today's policies and programmes could become the very cause of increased food insecurity in the future [8]. To feed the growing population, food is being produced at the cost of critical natural resources as evidenced by degradation of soil, lowering of water tables, clearing of forests [9, 10] and thus it poses a threat for the security of future.

Eradicating persistent food insecurity from India is a challenging task. Before designing and implementing the policy to address the food insecurity issue, it is imperative to have improved understanding on the regional factors responsible for it. The planning process in India is largely centralized. Many programmes continue to be designed with a national and state-level perspective. It is probably high time to change this approach. In this backdrop, the present paper construct district wise Sustainable Food Security Index of Uttar Pradesh for the year 2015-16 to characterize the districts in the state according to their relative sustainability status in terms of food security and to identify the specific dimensions that require prior policy attention for orientation of development programmes for ensuring food security for the future generations. The choice of the study area is guided by the fact that the state, despite having largest area and production share of food crops in the country, is home of a large number of food insecure households.

2. Material and methods

The major approaches used in the previous studies to assess the sustainability of a system in a particular region include computation of composite indices covering varied dimensions of sustainability [11, 12, 13, 14] and Response-Inducing Sustainability Evaluation (RISE) [15].

Nonetheless, both the techniques has its own utility; the present paper follows index based approach as it is more simple practical tool for indicating a set of interventions required to address the problem areas that impede sustainability. The composite index of sustainable food security has been constructed from its components – food availability, access and utilization.

2.1 Data

The study is based on district wise secondary data collected from various published and unpublished sources. The data pertaining to total geographical area, net sown area, gross cropped area, net irrigated area, area under leguminous crops, total foodgrain production, total forest cover, barren and un-culturable land and culturable waste land for the year 2014-15 were collected directly from the various publications of the Directorate of Economics and Statistics, Ministry of Agriculture and Farmer's Welfare such as Agricultural Situation in India and Agricultural Statistics of India.

Secondary data on the district-wise demographic and socio-economic parameters like geographical area, total population, household industry workers and other workers which collectively constitute as non-agricultural workers; non-workers as well as total workers, female literacy rate, infant mortality rate, percentage of population having access to safe drinking water, availability of health infrastructure (Sub centre, Public Health Centre, Community Health Centre, Sub Divisional hospital, District hospital) were generated from the official website of Census of India carried out in 2011.

The data on agricultural landholding and small and marginal farmers are available on the website of Agricultural Census, Department of Agriculture and Cooperation, Ministry of Agriculture and Farmer's Welfare. The information on the number of households and number of landless labour households was compiled from Socio-Economic & Caste census, 2011. Data regarding non-crop agricultural workers for every district were obtained from the latest (2012-13) available Economic Census of the state.

District wise data on livestock density, total livestock population of crossbred, indigenous cattle and buffalo were collected from 19th Livestock census (2012) published by the Department of Animal Husbandry, Dairying and Fisheries, Government of India. The milk production data of each district for the year were sourced from the report of National Dairy Development Board (NDDB).The data regarding district wise consumption of NPK fertilizers for the year 2014-15 were collected from Fertilizer Statistics, published by The Fertilizer Association of India.

The study has used district wise growth of daily mean temperature and rainfall for the period 1980-2009. The data on daily mean temperature at a spatial resolution of 0.5×0.5 degree and daily mean rainfall at a spatial resolution of 0.25 ×0.25 degree for the considered period were sourced from India Meteorological Department (IMD), Pune.

The district wise data showing unexploited ground water for future use for the year 2011 were sourced from Central Ground Water Board, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India. District wise data on population below poverty line for the year 2014-15 was collected from Statistical abstract of Uttar Pradesh.

2.2. Construction of sustainable food security index

2.2.1 Selection of indicators

The components of sustainable food security – availability, access and utilization were represented through 29 different indicators. These indicators were chosen from a broader list of indicators based on previous standard literature and discussion with experts. Glimpses of indicators under each component of food security are presented in Table 1 and have been discussed below.

Food availability: A total of thirteen indicators affecting the agricultural production system were selected out of which seven indicators, viz., cropping intensity, change in net sown area, food grain production per capita, irrigation intensity, fertilizer consumption, population density and milk productivity are pertaining to present security and other six indicators - per capita forest cover, unexploited ground water for future, degraded area to geographical area, leguminous crops in gross cropped area, growth rate of annual mean temperature, coefficient of variation of monthly mean rainfall represents future sustenance.

Cropping intensity is the raising of a number of crops on the same field during one agricultural year and is expressed as a ratio of gross cropped area to net sown area. This indicator is positively related to food availability i.e., higher the cropping intensity, higher will be the food availability in a region.

Change in the net sown area is considered as an important indicator for food availability as the districts where net sown area is expanding over time is better off in respect of present food security and vice-versa.

Food grain production per capita represents net availability of food to each and every individual and is basic for achieving the security of food and is measured as total food grain production of a

district divided by its population. The districts with higher per capita net availability of food are more secured in relation to those which have less availability.

Irrigation intensity is expressed as a ratio of net irrigated area to net sown area. It affects the food availability by contributing to the growth in the overall cropping intensity of a region. Therefore, the indicator positively influence the food availability in a region i.e., the districts with higher irrigation intensity have more availability of food and are more food secured.

Since higher *fertilizer consumption* augments the food production. Therefore, the districts with higher consumption of NPK fertilizes are taken as more food secure. *Milk productivity* also bears positive relation with food security of the region. Contrarily, *population density* has been defined as the number of persons per square kilometer and negatively affects the food availability of the region.

Per capita forest cover measures human pressure on forest and is calculated by dividing the total forest area of a district with its population. This indicator reflects the natural resource endowment of a region useful for further agricultural production by preserving its watersheds and thus has been included as a positive indicator of sustenance of food availability. Likewise, the districts with higher *unexploited ground water for future use* are considered to be more sustained in terms of food availability and thus more food secured for future generation.

Further, *degraded area to geographical area* is calculated by dividing the area under degraded land to total geographical area. Degraded land consists of barren and un-culturable land and culturable waste land. This indicator negatively influences the sustenance of food production as the districts with smaller percentage of degraded land are regarded as more sustained in contrast to others which have higher percentage of same.

Percentage of *leguminous crops in gross cropped area* is measured as the ratio of area under pulses to the total cropped area. The legume crop helps in restoring the soil fertility with the adoption of viable cropping pattern, thus ensures the sustenance of food production. Therefore, the districts with the higher percentage of area under legumes are more food sustained and secured.

The changes in the climatic parameters i.e., temperature and rainfall, over the years affects the production and productivity of crops and thus must be considered as important indicator of sustenance of food production as well as its availability. Therefore, *growth rate of annual mean temperature* and *coefficient of variation of monthly mean rainfall* for the time slice of 30 years

(1980-2009) were incorporated in the present study as an indicator of future sustenance of food availability.

Food access: The food access component of food security is related to the purchasing power of an individual which depends on income earned and is affected by number of indicators. *Below poverty line* and *non worker population* negatively affects the food access i.e., the population faces difficulty in purchasing sufficient food for their livelihood.

Table 1 Indicators and their functional relationship with sustainable food security

Component	Related with	Indicators	Unit	Relation with sustainable food security
Food Availability	**Present security**	Cropping Intensity	%	Direct
		Change in net sown area	%	Direct
		Food grain production per capita	kgs/month/person	Direct
		Irrigation Intensity	%	Direct
		Fertilizer consumption (NPK)	Tonnes/ha	Direct
		Population density	Person/Km^2	Inverse
		Milk Productivity	MT/milch animal/year	Direct
	Future sustenance	Per capita forest cover	Hectare (ha)	Direct
		Unexploited ground water for future	Hectare metre (ham)	Direct
		Degraded area to geographical area	%	Inverse
		Leguminous crops in gross cropped area	%	Direct
		Growth rate of annual mean temperature	%	Inverse
		Coefficient of variation of monthly mean rainfall	%	Inverse
Food Access	**Present security**	Below poverty line population	%	Inverse
		Non agricultural workers to total workers	%	Direct
		Number of milch animals per 000' population	No.	Direct
		Cross bred adoption rate	%	Direct
		Small and marginal farmers per 000' population	No.	Inverse
		Non worker population	%	Inverse
		Buffalo : Indigenous Cattle ratio	%	Direct
	Future sustenance	Average size of holding	Hectare (ha)	Direct
		Livestock density	No./km^2	Inverse
		Non crop agricultural workers	%	Direct
		Landless labour households to total households	%	Direct
		Instability in cereal production	%	Inverse
Food Utilization	**Present security**	Safe drinking water	%	Direct
		Infant Mortality Rate	%	Inverse
		Health infrastructure	No.	Direct
		Female literacy rate	%	Direct

The ratio of *non-agricultural worker to total worker* positively determines the security of food access as higher percentage of it reduces the dependence on primary sector (agriculture) through a shift to the higher income secondary sector (manufacturing & industry). Even the ratio of small and marginal farmers to the rural population which gives *small and marginal farmers per 000' population* is inversely related to food access security due to their low income and thus low purchasing ability. Further, the livestock sector which is prime source of income along with crop cultivation for rural population can't be overlooked as food access is concerned. Larger *number of milch animals per 000' population* and higher percentage of *cross bred adoption rate* as well as *buffalo to indigenous cattle ratio* in a district directly contribute to earnings of rural population, indicates higher food self-sufficiency and thus more food secure. *Average size of land holding* facilitates adoption of modern technology on farm and thus increases income of the farm households. Therefore, it bears positive relation with the sustenance of food access. *Livestock density* negatively influence the food access sustenance as more livestock population put excess pressure on land due to overgrazing and thus results in degradation. *Percentage of non-crop agricultural workers* and *landless labour households to total households* contribute directly to security of future generation since they reduce the pressure on land and natural resources through diversification towards allied activities and thus improve the livelihood access for future. The districts with higher instability in cereal production are less sustained with respect to food access and those with less instability are more sustained.

Food utilization: Among the indicators of food utilization, districts with higher *female literacy rate*, better *access to safe drinking water*, significant *health infrastructural* development and low *infant mortality rate* are supposed to be in much better condition in context of absorption of food than that of other districts and thus are more food secured.

2.2.2 Normalization of indicators

As the indicators were measured in different units and scale, it becomes necessary to convert them into some standard units though normalization to avoid any kind of scale biasness in the result. Various methods have been suggested in literature to normalize the influence of units and scale like ranking, standardization, min-max and each of them has its own merits and demerits though choice of any of these is not a value free decision. In the present study, following the generalization of relative approach underlying the Human Development Index developed by [16], min-max technique has been used to normalize the indicators.

$$I_{ijk} = \frac{X_{ijk} - Min\ X_{ijk}}{Max\ X_{ijk} - Min\ X_{ijk}}$$ …… (1) when indicator has +ve association with the component

$$I_{ijk} = \frac{Max\ X_{ijk} - X_{ijk}}{Max\ X_{ijk} - Min\ X_{ijk}}$$ ….. (2) when indicator has -ve association with the component

where,

X_{ijk} = value of i^{th} indicator representing j^{th} component of Sustainable Food Security Index of k^{th} district.

2.2.3 Assigning weights to indicators and construction of Sustainable Food Security Index

Based on the past reviewed literature [17, 18, 19, 20, 21] the 'Principal Component Analysis (PCA)' is supposed to be the most reliable method for assigning weights to the indicators while constructing food security index. PCA is a multivariate statistical technique helps to compress the data by reducing the number of dimension without much loss of information and thus creates a new set of variables out of a given set of variables (Xj , i=1, 2, 3, …., k) called principal components (Pi). In original data indicators may be correlated and PCA help to transform them into uncorrelated variables. Following steps were used for calculating the weights through PCA and construction of indices for each dimension of food security:

Step- I : Compute $X = X'_s X_s$

$(k \times k)$ $(k \times n)$ $(n \times k)$

Where, X_s (n x k) is the normalized data matrix, X'_s $(n \times k)$ is the transpose of normalized matrix and, n and K are the number of observations (districts) and number of indicators used.

Step- II : Conversion of the array (**X**) into symmetric matrix.

Step –III : Eigen value decomposition of the symmetric matrix to get principal components.

Step – IV : Selection of eigen vectors corresponding to the largest eigen value i.e., first principal components say 'W (k x 1)' explaining the maximum variation.

Step –V : Compute $Y = X_s W$

$(nx1) \quad (nxk)(kx1)$

Step-VI : Construction of final index by dividing the Y with sum of the first principal components.

The above procedure was used for the development of separate indices for each component of sustainable food security viz., Index of food availability security (FAI), Index of food availability sustenance (FSI), Index of food access security (FASI), Index of food access sustenance (FASUI) and Index of food utilization (FUI). The composite Sustainable Food Availability Index (SFAI) and Sustainable Food Access Index (SFAcI) was computed as the weighted mean of their respective components as:

$$SFAI = FAI*0.55 + FSI*0.45 \quad \ldots\ldots\ldots\ldots\ldots (4)$$

$$SFAcI = FASI*0.60 + FASUI*0.40 \quad \ldots\ldots\ldots\ldots (5)$$

where the weights (0.55, 0.45, 0.60, 0.40) has been assigned depending on their share in total indicators considered for the respective composite index [22].

Finally the Sustainable Food Security Index (SFSI) for each district (k) was calculated as weighted mean of the three composite indices viz., Sustainable Food Availability Index (SFAI), Sustainable Food Access Index (SFAcI) and Food Utilization Index (FUI).

$$SFSI_k = \frac{(W_1 * SFAI_k) + (W_2 * SFAcI_k) + (W_2 * FUI_k)}{\sum_{i=1}^{3} W_i} \quad \ldots\ldots\ldots (6)$$

where W_i is the weights apportioned to respective components of SFSI, since SFSI is composite in nature and the relative magnitude of its components varies across regions. W_i is calculated as the ratio of inverse of the proportional contribution of SFAI, SFAcI and FUI to the sum of all the three inverse proportions for the three components for each region and for each component across the regions [14] and thus gives more weight to weaker components in a region rather than equal weights. Higher value of SFSI indicated higher security as well as sustainability of the region.

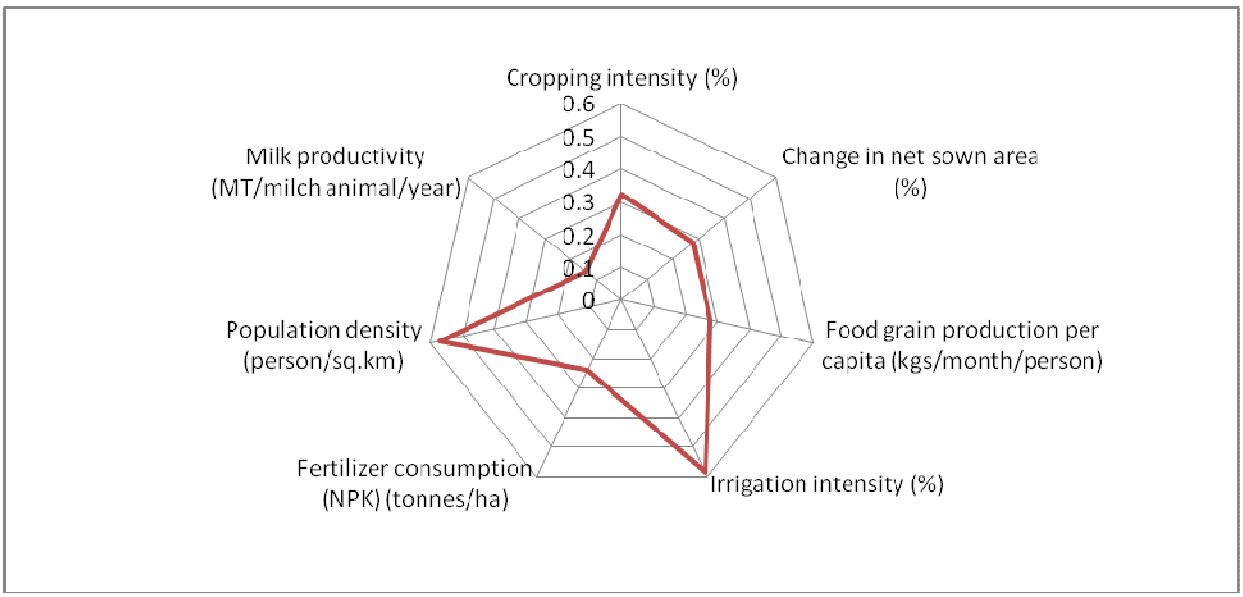
3. Results and discussion

The discussion on the indices of the components of sustainable food security precedes the results of sustainable food security index of the study area which has been delineated into four economic regions (Annexure I).

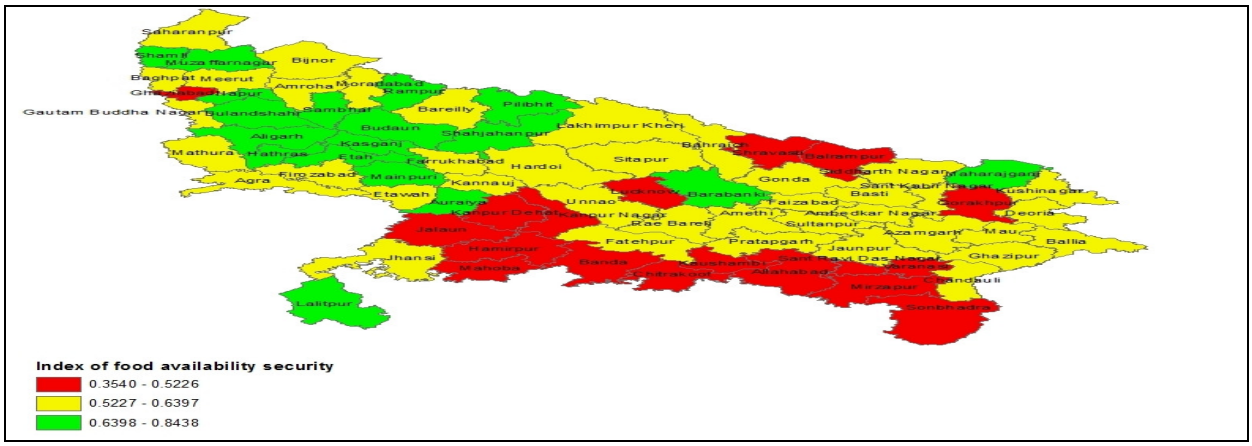
3.1 Index of food availability security

The first principal component explained around 90 per cent variation in the state (Annexure II). The figure 1 shows the importance of indicators responsible for the security of food availability which is reflected from their weights obtained from principal component analysis. As revealed by the value of weights, irrigation intensity was the most important factor contributing to the security of food availability followed by population density. Most of the districts lying in the Western region like Kasganj, Sambhal, Pilibhit etc. were highly secured in terms of food availability; however Bundelkhand (Chitrakoot, Hamirpur etc.), Central (Kanpur Nagar) and Eastern (Sonbhadra, Varanasi etc.) regions were medium to lesser secured in terms of food availability (Map 1). The lowest percentage of net irrigated area to the net sown area in Sonbhadra (29%) and Chitrakoot (43%) pushed theses districts to the bottom in food availability security status.

Fig 1: Weights for the indicators of food availability security



Map 1: District wise food availability security map

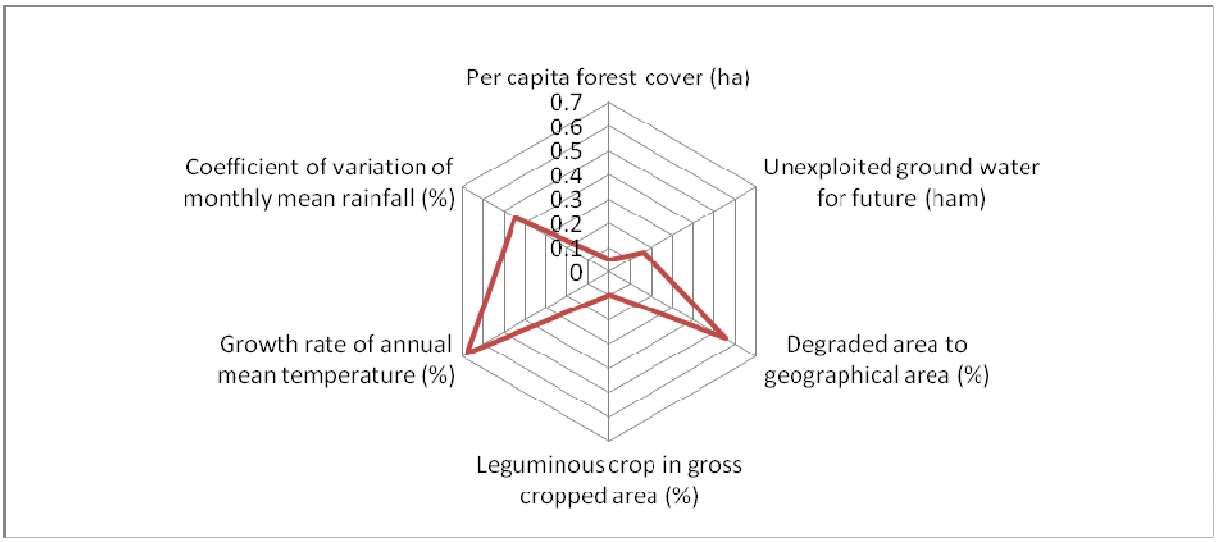


3.2 Index of food availability sustenance

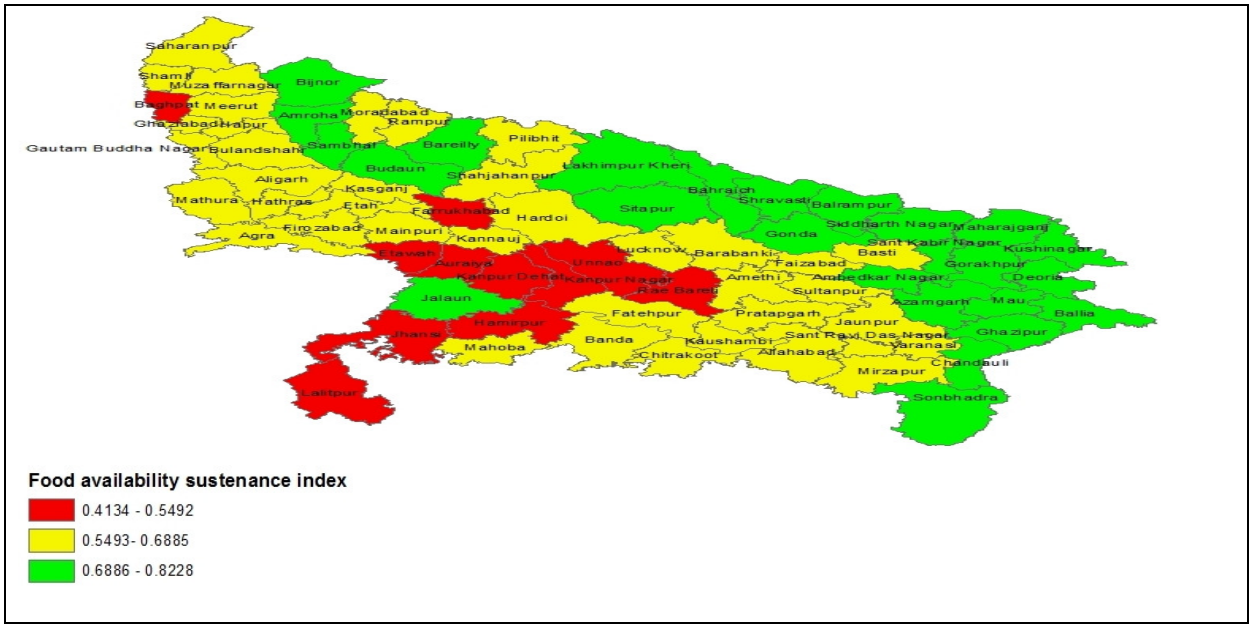
The sustenance index of food availability ranged from 0.413 in Hamirpur to 0.823 in Chandauli. The first principal component explained around 90 per cent variation; and the weights obtained for each indicator from principal component analysis (PCA) is given in fig.2. Growth rate of annual mean temperature gained prime importance in influencing sustenance of food availability. Other factors of high influence were proportion of degraded area to geographical area and coefficient of variation of monthly mean rainfall. Interestingly, the climatic parameters, the consideration of which has been completely neglected in earlier literatures in constructing index at national [22] and regional level [23] gained importance in influencing the sustenance of food availability in the present study area.

Map 2 shows that the districts in the Eastern region were ranked higher in the index of food availability sustenance and most of the districts in the Western region lied in the moderate range of the index. The district which stood lower in terms of food availability sustenance was in Bundelkhand region (Hamirpur, Jhansi etc.), Central region (Kanpur Nagar, Rae Bareli etc.) and Western region (Baghpat, Etawah, Auraiya). Percentage of degraded land to geographical area was the reason behind the low sustenance of these districts; apart from this, owing to the highest growth rate of annual mean temperature in Hamirpur, it stood least sustained in terms of food availability. The coefficient of variation of mean monthly rainfall in the aforesaid districts has also added to the lower sustenance of food availability.

Fig. 2 Weights for the indicators of food availability sustenance



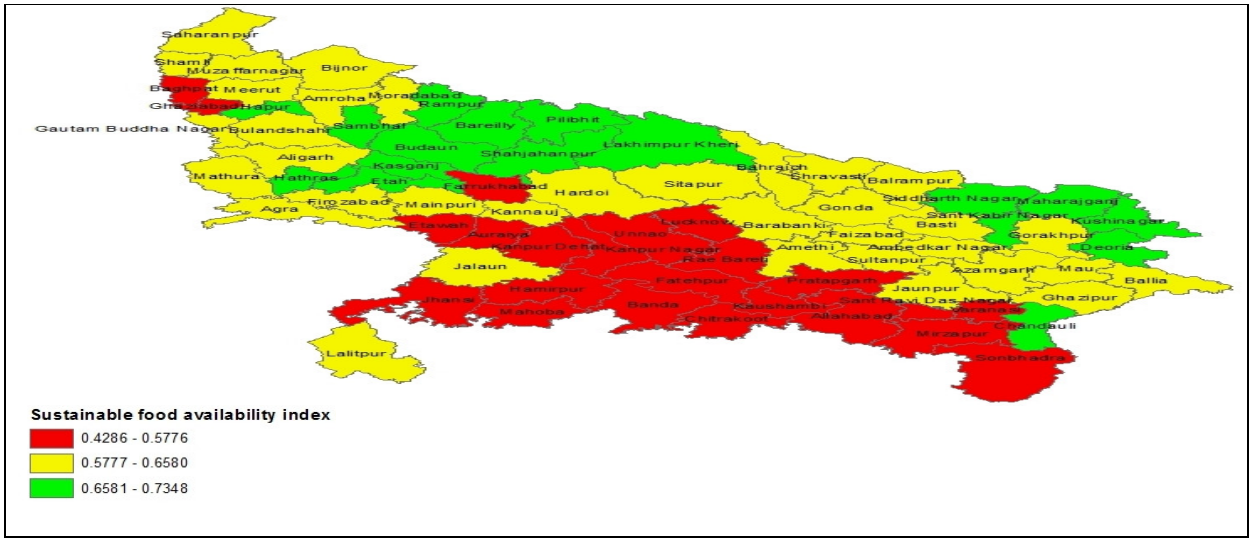
Map 2: District wise food availability sustenance map



3.3 Sustainable food availability index

As discussed in the methodology section, based on the two indices viz., index of food availability security and index of food availability sustenance, a composite sustainable food availability index has been prepared. The district wise index value along with their ranking is given in Annexure- III. Almost all of the districts lying in the Bundelkhand region and few districts of Central (Kanpur Nagar, Lucknow, Bara Banki etc.) and Eastern region (Sonbhadra, Mirzapur, Allahabad, Varanasi) were rated low in sustainable food availability (Map 3).

Map 3: District wise sustainable food availability map

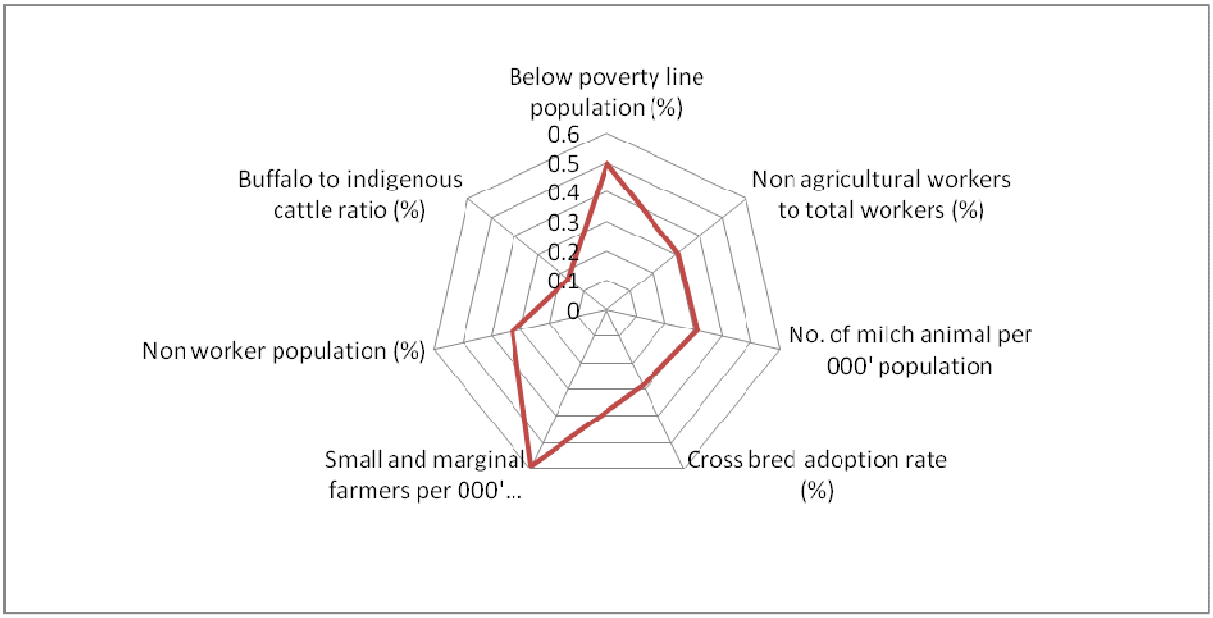


The districts of Baghpat and Ghaziabad which lie in the Western region of the state were also fell into lower range of sustainable food availability index owing to their lower indices value of food availability security and food availability sustenance. Further, few districts of north-western region (Pilibhit, Rampur, Bareilly) and north-eastern region (Maharajganj, Deoria, Kushinagar) were rated high in sustainable food availability (Map 3).

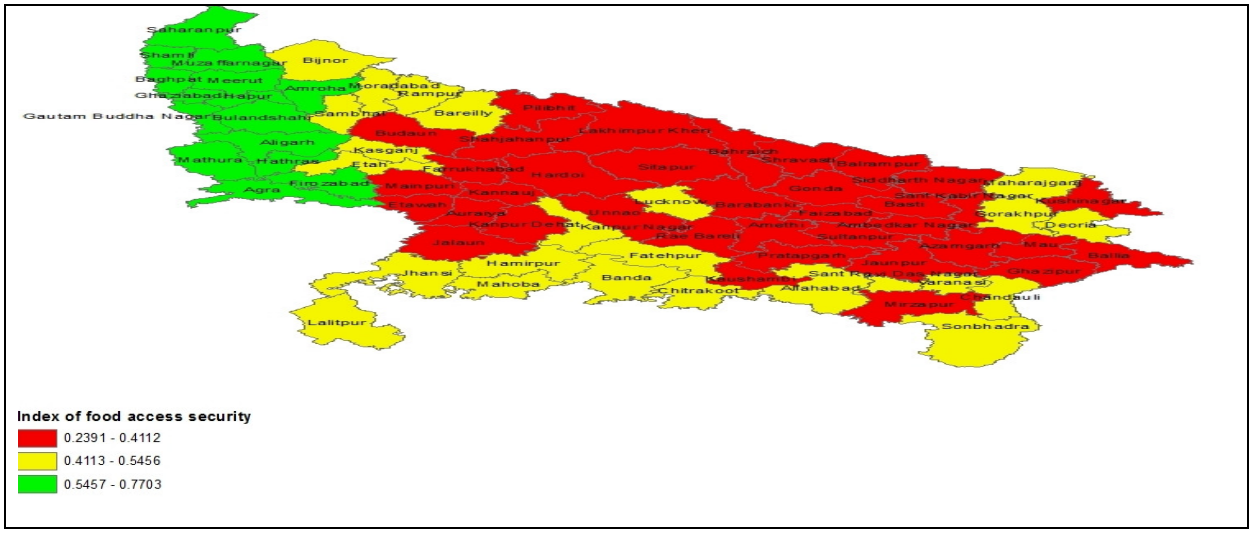
3.4 Index of food access security

Weights obtained by PCA revealed that number of small and marginal farmers as the most important indicator of food access security in Punjab (Fig. 3). The other indicators of high influence on food access security were below poverty line population, percentage of non worker population and number of milch animals. Most of the districts in Central and Eastern region and few of the Western region (Shahjahanpur, Mainpuri, Budaun, Pilibhit, Etawah) were rated lower in the food access security index (Map 4) owing to the relatively higher number of people living below poverty, large number of non working population and lesser number of milch animals. The districts lying in the Bundelkhand region and some of the districts in Eastern (Sonbhadra, Varanasi, Allahabad, Gorakhpur, Deoria) and Western (Bijnor, Etah, Moradabad, Sambhal, Bareilly) region fell into the moderate range (0.4113-0.5456) of food access security index.

Fig. 3 Weights for the indicators of food access security



Map 4: District wise food access security map

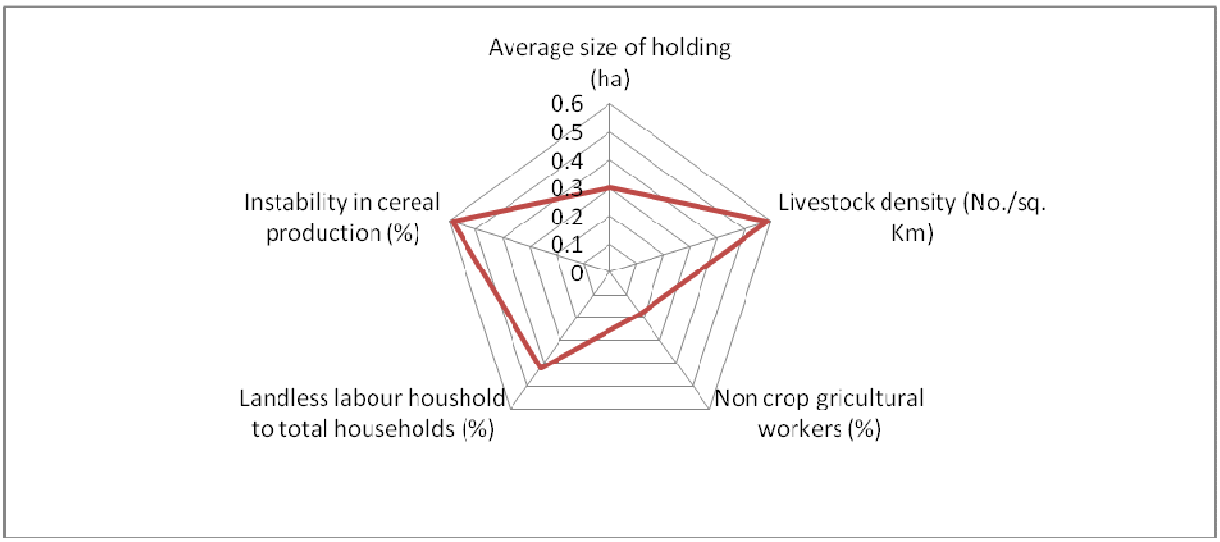


3.5 Index of food access sustenance

The first principal component explained about 88 per cent variation in the state; and the weighs obtained for each indicator from principal component analysis (PCA) is given in Figure 4. The results revealed that the three indicators namely livestock density, percentage of landless labour

households and instability in cereal production were the top three indicators influencing the sustenance of food access.

Fig. 4 Weights for the indicators of food access sustenance

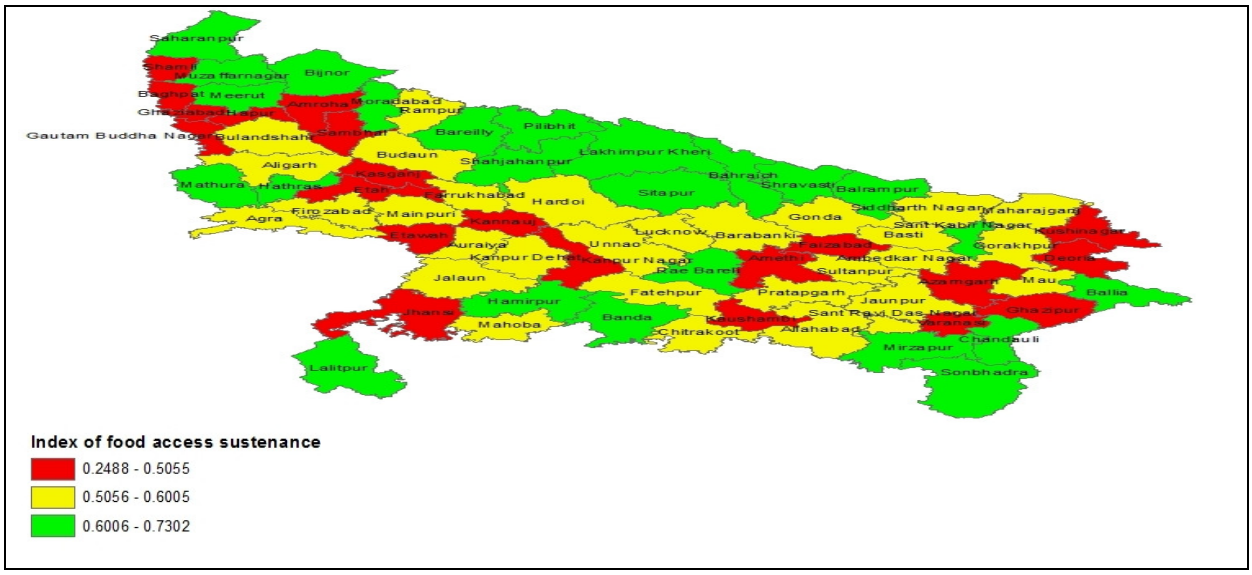


Districts in the northern (Pilibhit, Kheri, Bahraich, Bareilly etc.) and north-western (Saharanpur, Bijnor, Meerut etc.) part of the state were rated relatively high in terms of food access sustenance, whereas a large number of districts of central and eastern part of the state were in moderate range (0.5056 to 0.6005) in index of food access sustenance. It is important to mention here that a good number of districts (28%), though sparsely located, were in bottom range of food access sustenance index (Map 5).

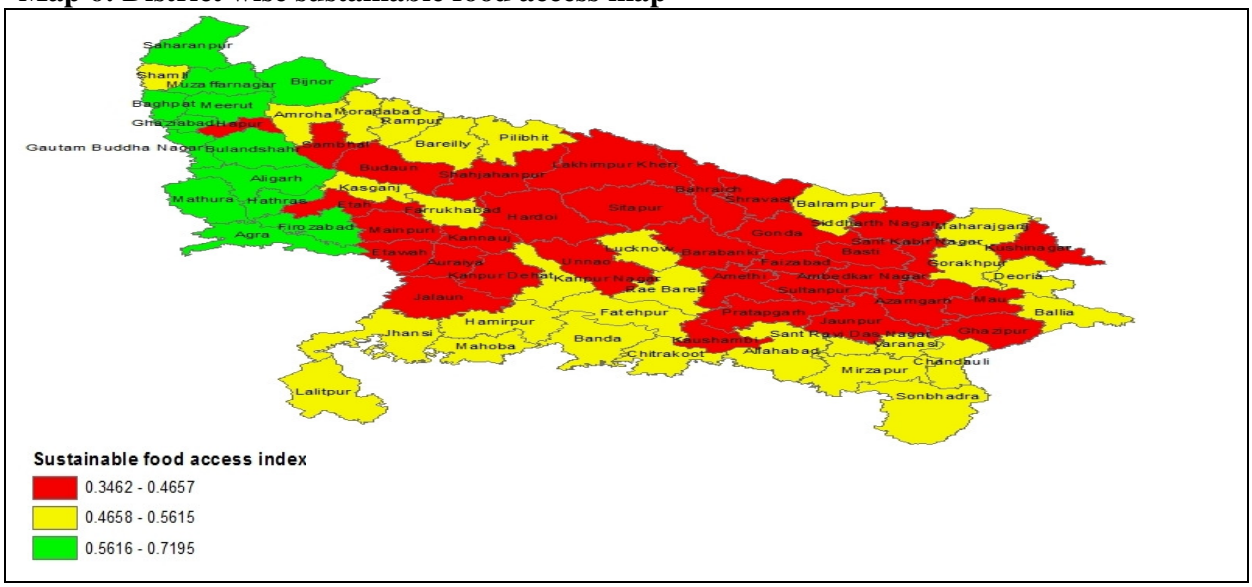
3.6 Sustainable food access index

The district wise value of sustainable food access index and their corresponding ranking for the state is given in Annexure III. Most of the districts in Central and Eastern region which were rated relatively lower in the index of food access security also obtained lower value in the sustainable food access index; however some of the districts in the Western region (Muzaffarnagar, Saharanpur, Meerut, Bijnor etc.) were ranked higher in the index. Remaining all other districts in the Bundelkhand (Lalitpur, Jhansi, Mahoba etc.) and Eastern (Sonbhadra, Ballia, Deoria etc.) region lied in moderate range of sustainable food access index (Map 6).

Map 5: District wise food access sustenance map



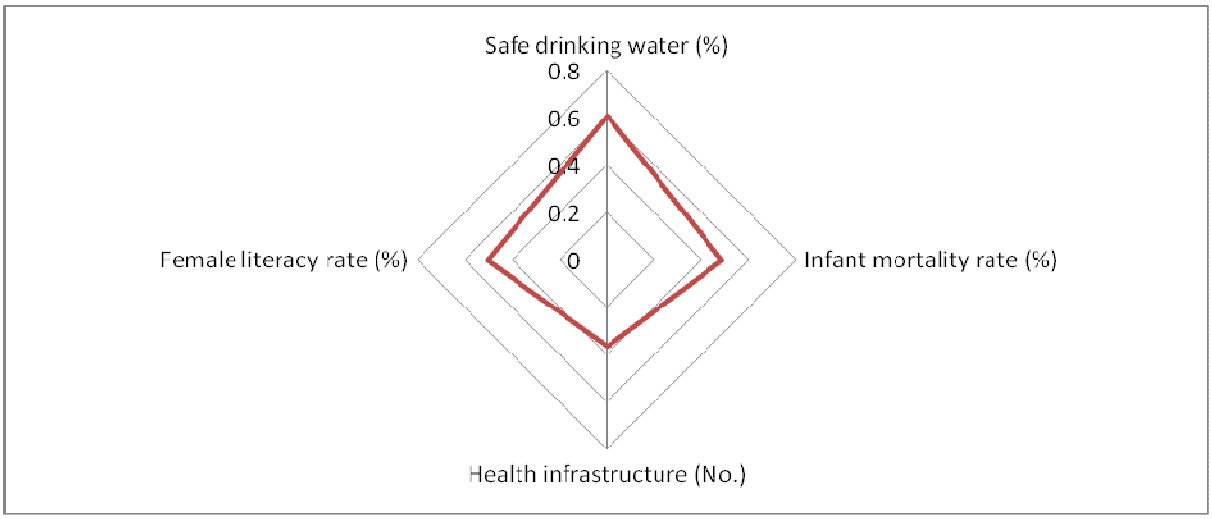
Map 6: District wise sustainable food access map



3.7 Food utilization index

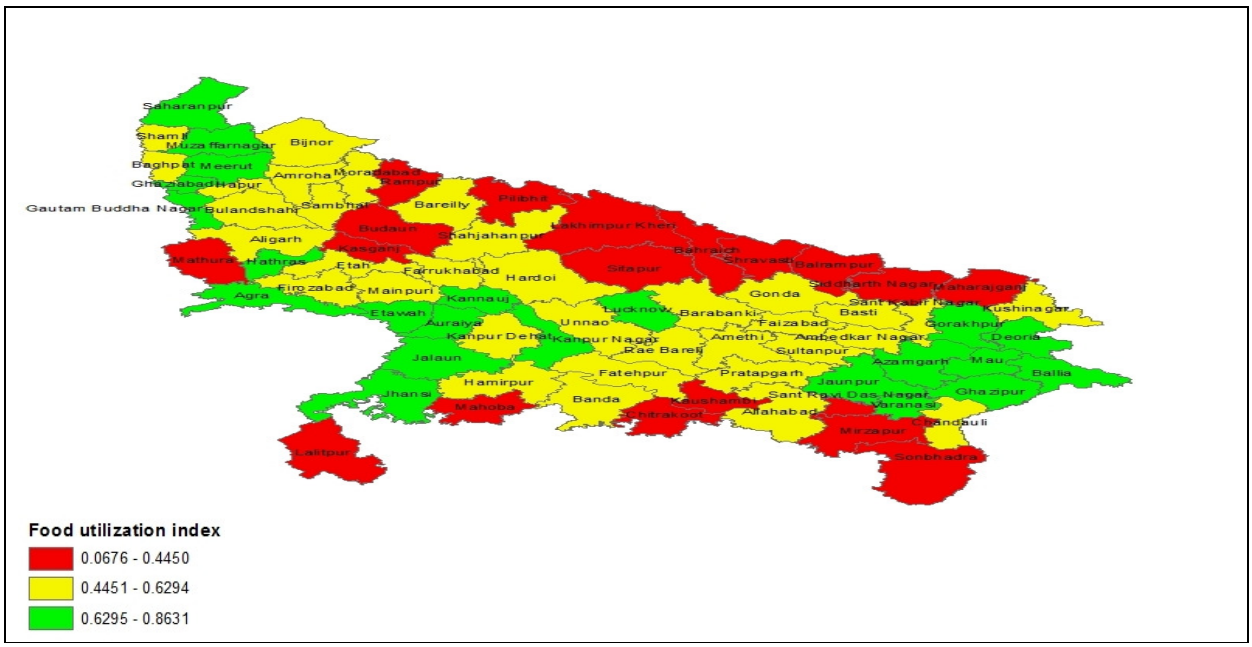
Around 91 per cent variation was explained by the first principal component (Annexure II), and weights by PCA revealed that access to safe drinking water was the most important indicator. The other important indicators were female literacy rate and infant mortality rate (Fig. 5). The availability of health infrastructure got the lowest weight. The districts lying in northern and north-eastern region were rated medium to low in terms of food utilization.

Fig. 5 Weights for the indicators of food utilization



Few districts in the southern part of the state (Lalitpur, Mahoba, Chitrakoot and Kaushambi) were also in the bottom range of the food utilization index (Map 7). Good access of safe drinking water in the eastern districts (Ballia, Deoria, Azamgarh, Ghazipur etc.) and few districts in the western part (Agra, Etawah, Hathras etc.) of the state were the prime reason behind their higher index value of food utilization.

Map 7: District wise food utilization map



3.8 Sustainable Food Security Index

The sustainable food security index was estimated as weighted mean of the three composite indices viz., Sustainable Food Availability Index (SFAI), Sustainable Food Access Index (SFAcI) and Food Utilization Index (FUI). The district wise index values along with their ranking are given in Annexure III. Districts lying in extreme Western (Saharanpur, Baghpat, Meerut etc.) and Eastern (Ballia, Deoria, Mau etc.) parts of the state were highly sustainable in terms of overall food security while a large number of district fell into the moderate range of sustainable food security index (Map 8).

Map 8: District wise sustainable food security map

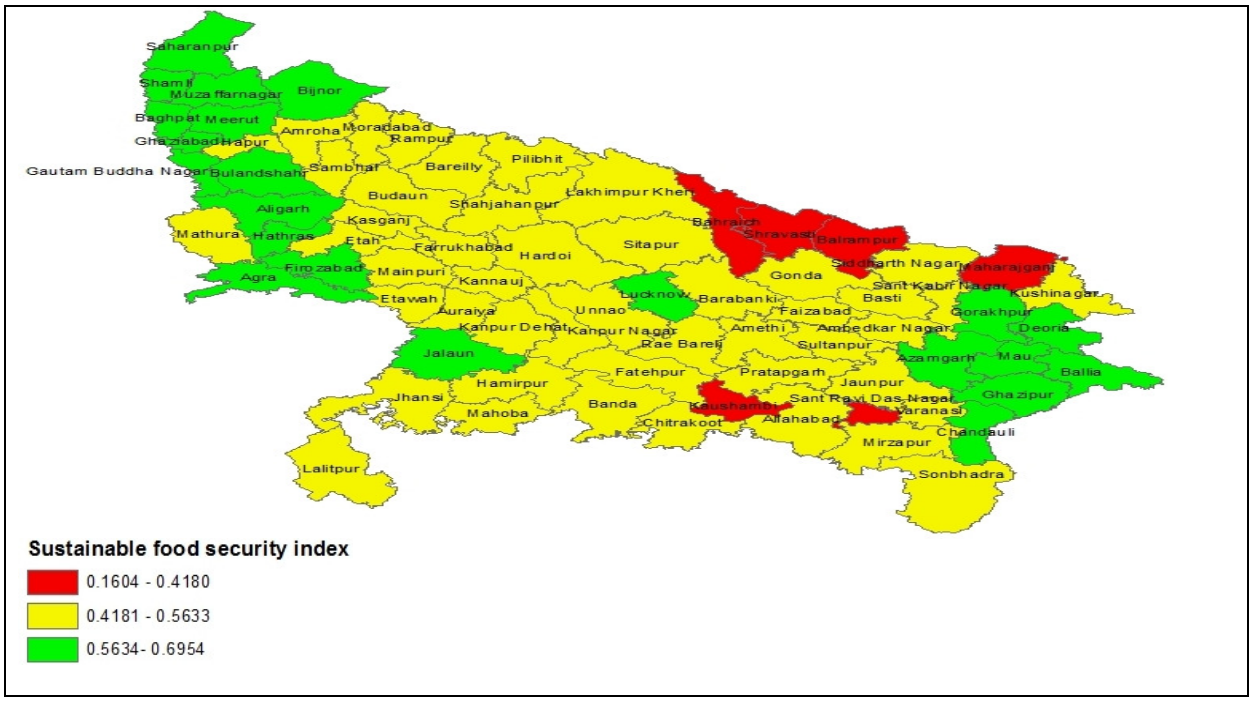


Table 2, which presents the numbers of districts in different sustainable food security class of the study area shows that only 8 per cent of the districts occupied the bottom range of sustainable food security index and most of them were moderately sustainable (61%).

Table 2: Number of districts in different sustainable food security class in Uttar Pradesh

Region	Total districts	Sustainable Food Security Class		
		High	Moderate	Low
Uttar Pradesh	75	23	46	6
		(31)	(61)	(8)

Note: Figures in parentheses are per cent of districts in different sustainable food security class

The rank correlation coefficient among the sustainable food security index and its components, viz., sustainable food availability, sustainable food access and food utilization was calculated (Table 3) and analyzed to understand the relative importance of the components contributing to the sustainability of food security. All the three components were positively related with the sustainable food security as per *a-priori* expectations. The significant negative correlation between sustainable food availability and food utilization signifies that the districts where physical availability to food is better, stands lower in food utilization ladder.

Table 3. Rank correlation coefficient among sustainable food security and its components across the study region

	Sustainable Food Availability	Sustainable Food Access	Food Utilization	Sustainable Food Security
Sustainable Food Availability	1.000			
Sustainable Food Access	-0.087	1.000		
	(0.272)			
Food Utilization	-0.153**	0.076	1.000	
	(0.052)	(0.337)		
Sustainable Food Security	0.041	0.372*	0.615*	1.000
	(0.602)	(0.000)	(0.000)	

*Significant @ 1%, **Significant @ 5 %, *** Significant @ 10 %

Note: Figures in parentheses indicates p value

Further, correlation of food utilization with sustainable food security was highest (r = 0.615) followed by food access (r = 0.372) indicating that these two are more detrimental for the sustainability of food security status in the districts of Uttar Pradesh.

Relative status of sustainable food availability, sustainable food access and food utilization level of low sustainable food secure districts (Table 4) revealed that the districts (Kaushambi, Bahraich and Shravasti) were less sustainable in terms of food security owing to the low sustainable food access as well as low utilization level confirming the expectations based on the findings of Table 3.

Table 4. Relative status of components of sustainable food security in low sustainable food secure districts

Study area	Sustainable food security level	Districts	Sustainable food availability level	Sustainable food access level	Food utilization level
Uttar Pradesh	Low	Maharajganj	High	Moderate	Low
		Sant Ravidas Nagar	Low	Moderate	Low
		Kaushambi	Low	Low	Low
		Balrampur	Moderate	Moderate	Low
		Bahraich	Moderate	Low	Low
		Shravasti	Moderate	Low	Low

However, few districts (Maharajganj, Sant Ravidas Nagar and Balrampur) were having moderate access to food but have very poor utilization that pushes them in low sustainable food security class. Further, the high rating of the Maharajganj district in terms of sustainable food availability didn't helped much in pulling it from low sustainable food security status. Therefore the districts experiencing low food access with low or poor food utilization should be targeted areas and must be taken on priority for improving the sustainable food security status of the respective area.

4. Conclusions

The district wise assessment of sustainable food security status of the state envisages several policy measures which are critical to improve the overall sustainability of food security in Uttar Pradesh. The findings of the study brought out that bringing more area under irrigation in Bundelkhand region and Sonbhadra district of Eastern region is particularly important for improving the present security of food availability. As these regions are drought prone areas of the state [24]; investment to create on-farm structures for harvesting, storage and distribution of rainwater would be more policy imperative. Further the study revealed that climatic variations and the degraded land in the state are looming threat for sustenance of food availability. Therefore it draws attention of the policy makers for development of regional climate change adaptation and resilience enhancement strategies, especially for Bundelkhand region of Uttar Pradesh where variability in the climatic parameters is comparatively higher than other parts of the state. Further, strict land use strategy and efficient watershed management practices would be instrumental for reclaiming degraded land.

Reduction in the rural poverty ratio and improving the milch herd population is found to be critical for improving food access security in Eastern and Central region; hence measures to create more off-farm employment opportunities and promotion of sex semen technology would be more policy imperative.

Besides, in the regions which are rated low in terms of food utilization in the study area, all stakeholders should enact measures to improve female literacy rate and access of safe drinking water for ensuring overall sustainable food security of the study regions.

As the study establishes that improving food access and utilization capacity are more critical than food availability for ensuring sustainable food security of the study area, the findings of the study will help the decision makers at all level of decision making in targeting the districts where appropriate measures are to be taken up for strengthening the food access and utilization.

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Annexures

Annexure I: Economic Region of Uttar Pradesh

S.No.	Region	Districts
1.	Western	Agra, Mainpuri, Firozabad, Aligarh, Kasganj, Bareilly, Badaun, Bulandshar, Etah, Etawah, Farrukhabad, Mathura, Meerut, Ghaziabad, Muradabad, Pilibhit, Rampur, Muzaffarnagar, Saharanpur, Bijnor, Shahjahanpur, Baghpat, Gautam Buddha Nagar, Hathras, Amroha, Kannauj, Auriya
2.	Central	Bara Banki, Fatehpur, Hardoi, Kanpur Nagar, Kanpur Dehat, Kheri, Lucknow, Raebareli, Sitapur, Unnao
3.	Eastern	Allahabad, Kaushambi, Azamgarh, Mau, Ballia, Bahraich, Basti. Siddharth Nagar, Deoria, Faizabad, Ghazipur, Gonda, Gorakhpur, Maharajganj, Jaunpur, Mirzapur, Sonbhadra, Pratapgarh, Sultanpur, Varanasi, Balrampur, Shravasti, Chandauli, Sant Ravidas Nagar, Kushi Nagar, Sant Kabir Nagar, Ambedkar Nagar
4.	Bundelkhand	Jhansi, Jalaun, Hamirpur, Mohaba, Banda, Chtirakoot, Lalitpur

Source: Government of Uttar Pradesh, 2009 [25]

Annexure II: First principal component of different dimensions of sustainable food security

Dimensions of sustainable food security	Uttar Pradesh	
	Eigen value	Proportion
Food availability security	152.04	0.9190
Food availability sustenance	126.46	0.9068
Food access security	101.27	0.8354
Food access sustenance	104.90	0.8840
Food utilization	94.16	0.9140

Annexure III

Districts wise rank and indices of sustainable food availability and its components in Uttar Pradesh

District	Index of Food Availability Security		Index of Food Availability Sustenance		Sustainable Food Availability Index	
	Index value	Rank	Index value	Rank	Index value	Rank
Kasganj	0.8439	1	0.6017	53	0.7349	1
Chandauli	0.6390	20	0.8228	1	0.7217	2
Maharajganj	0.6510	17	0.8005	5	0.7183	3
Sambhal	0.7097	3	0.7156	19	0.7123	4
Kheri	0.6398	19	0.7911	6	0.7079	5
Pilibhit	0.7096	4	0.6885	26	0.7001	6
Budaun	0.6572	16	0.7416	15	0.6952	7
Siddharth Nagar	0.5973	38	0.8085	3	0.6923	8
Bareilly	0.6133	28	0.7472	13	0.6736	9
Kushi Nagar	0.5657	52	0.8046	4	0.6732	10
Shahjahanpur	0.6843	6	0.6594	35	0.6731	11
Hathras	0.6652	12	0.6745	32	0.6694	12
Deoria	0.5916	41	0.7567	12	0.6659	13
Etah	0.6686	10	0.6606	34	0.6650	14
Rampur	0.6618	15	0.6671	33	0.6641	15
Hapur	0.6646	13	0.6579	36	0.6616	16
Sant Kabir Nagar	0.5767	51	0.7626	9	0.6603	17
Ambedkar Nagar	0.6244	25	0.6992	24	0.6581	18
Gonda	0.6104	31	0.7104	22	0.6554	19
Azamgarh	0.6078	32	0.7119	20	0.6546	20
Mau	0.5943	40	0.7282	17	0.6546	21
Mainpuri	0.7061	5	0.5901	55	0.6539	22
Amroha	0.6053	34	0.7112	21	0.6529	23
Bulandshahr	0.6708	9	0.6282	44	0.6516	24
Amethi	0.6280	23	0.6788	28	0.6508	25
Ballia	0.5594	54	0.7586	11	0.6490	26
Bahraich	0.5359	55	0.7866	7	0.6487	27
Bijnor	0.6038	35	0.7027	23	0.6483	28
Sitapur	0.6012	36	0.6984	25	0.6450	29
Shravasti	0.5055	61	0.8104	2	0.6427	30
Moradabad	0.6074	33	0.6835	27	0.6416	31
Gorakhpur	0.5227	58	0.7863	8	0.6413	32
Ghazipur	0.5790	49	0.7172	18	0.6412	33
Bara Banki	0.6767	7	0.5960	54	0.6404	34
Shamli	0.6746	8	0.5891	56	0.6362	35

Lalitpur	0.7398	2	0.5066	68	0.6349	36
Meerut	0.5980	37	0.6766	30	0.6334	37
Muzaffarnagar	0.6426	18	0.6134	50	0.6295	38
Hardoi	0.6322	22	0.6253	47	0.6291	39
Sultanpur	0.5840	45	0.6750	31	0.6250	40
Jaunpur	0.5911	42	0.6551	37	0.6199	41
Faizabad	0.6111	30	0.6278	45	0.6186	42
Firozabad	0.5900	43	0.6505	39	0.6173	43
Aligarh	0.6633	14	0.5580	64	0.6159	44
Kannauj	0.5845	44	0.6534	38	0.6155	45
Saharanpur	0.5947	39	0.6180	48	0.6052	46
Basti	0.5816	48	0.6333	43	0.6049	47
Jalaun	0.4930	64	0.7284	16	0.5989	48
Mathura	0.6277	24	0.5621	63	0.5982	49
Balrampur	0.4581	66	0.7625	10	0.5951	50
Agra	0.5834	46	0.6060	52	0.5936	51
Gautam Buddha Nagar	0.5357	56	0.6424	41	0.5837	52
Auraiya	0.6682	11	0.4670	72	0.5777	53
Unnao	0.6199	26	0.5238	66	0.5767	54
Jhansi	0.6123	29	0.5157	67	0.5688	55
Pratapgarh	0.5598	53	0.5759	60	0.5670	56
Farrukhabad	0.5787	50	0.5493	65	0.5655	57
Baghpat	0.6324	21	0.4818	70	0.5646	58
Mirzapur	0.5109	59	0.6099	51	0.5554	59
Kaushambi	0.5055	60	0.6161	49	0.5553	60
Mahoba	0.4531	68	0.6785	29	0.5545	61
Fatehpur	0.5345	57	0.5667	62	0.5490	62
Etawah	0.6144	27	0.4618	73	0.5457	63
Sant Ravidas Nagar	0.4560	67	0.6343	42	0.5362	64
Allahabad	0.5050	62	0.5727	61	0.5354	65
Raebareli	0.5832	47	0.4671	71	0.5310	66
Sonbhadra	0.3540	75	0.7470	14	0.5309	67
Varanasi	0.4521	69	0.6258	46	0.5303	68
Lucknow	0.4650	65	0.5878	57	0.5203	69
Banda	0.4049	72	0.6452	40	0.5130	70
Kanpur Dehat	0.5026	63	0.4959	69	0.4995	71
Ghaziabad	0.4024	73	0.5761	59	0.4805	72
Chitrakoot	0.3649	74	0.5842	58	0.4636	73
Kanpur Nagar	0.4229	71	0.4445	74	0.4327	74
Hamirpur	0.4410	70	0.4134	75	0.4286	75

Districts wise rank and indices of sustainable food access and its components in Uttar Pradesh

District	Index of Food Access Security		Index of Food Access Sustenance		Sustainable Food Access Index	
	Index value	Rank	Index value	Rank	Index value	Rank
Meerut	0.7602	2	0.6587	10	0.7196	1
Baghpat	0.7703	1	0.5006	56	0.6624	2
Bulandshahr	0.7107	5	0.5897	28	0.6623	3
Muzaffarnagar	0.6602	6	0.6500	11	0.6561	4
Ghaziabad	0.7425	3	0.4933	59	0.6428	5
Mathura	0.6346	8	0.6393	14	0.6365	6
Saharanpur	0.5942	11	0.6780	7	0.6277	7
Gautam Buddha Nagar	0.7123	4	0.4894	61	0.6232	8
Aligarh	0.6377	7	0.5878	30	0.6177	9
Hathras	0.5793	13	0.6442	12	0.6052	10
Agra	0.6282	9	0.5432	42	0.5942	11
Firozabad	0.5829	12	0.5760	33	0.5801	12
Bijnor	0.5065	23	0.6793	6	0.5756	13
Lalitpur	0.5142	18	0.6327	17	0.5616	14
Chandauli	0.4561	32	0.7113	2	0.5582	15
Moradabad	0.5103	20	0.6263	22	0.5567	16
Amroha	0.5690	15	0.4763	66	0.5319	17
Allahabad	0.5292	17	0.5181	53	0.5248	18
Banda	0.4463	35	0.6392	15	0.5235	19
Shamli	0.5710	14	0.4512	69	0.5231	20
Mahoba	0.5085	21	0.5327	46	0.5182	21
Sonbhadra	0.4160	39	0.6701	9	0.5176	22
Hamirpur	0.4358	38	0.6396	13	0.5173	23
Mirzapur	0.3896	46	0.7051	3	0.5158	24
Gorakhpur	0.4587	31	0.5981	26	0.5145	25
Bareilly	0.4456	36	0.6103	23	0.5115	26
Rampur	0.4825	27	0.5539	38	0.5110	27
Sant Ravidas Nagar	0.5081	22	0.5099	54	0.5088	28
Lucknow	0.4673	29	0.5709	34	0.5087	29
Pilibhit	0.3607	59	0.7303	1	0.5085	30
Varanasi	0.5456	16	0.4353	70	0.5015	31
Raebareli	0.3822	50	0.6795	5	0.5011	32
Deoria	0.4890	25	0.4946	58	0.4913	33
Kanpur Nagar	0.4865	26	0.4957	57	0.4902	34

Fatehpur	0.4467	34	0.5498	39	0.4880	35
Ballia	0.3910	45	0.6319	18	0.4873	36
Maharajganj	0.4475	33	0.5455	41	0.4867	37
Chitrakoot	0.4368	37	0.5613	37	0.4866	38
Farukkhabad	0.4113	40	0.5972	27	0.4856	39
Kasganj	0.5140	19	0.4318	71	0.4811	40
Balrampur	0.3742	52	0.6286	20	0.4759	41
Jhansi	0.5042	24	0.4257	73	0.4728	42
Sant Kabir Nagar	0.3568	61	0.6292	19	0.4658	43
Hapur	0.6041	10	0.2488	75	0.4620	44
Barabanki	0.3757	51	0.5887	29	0.4609	45
Sambhal	0.4618	30	0.4588	68	0.4606	46
Sitapur	0.3472	62	0.6272	21	0.4592	47
Gonda	0.3832	48	0.5679	35	0.4571	48
Sultanpur	0.3697	56	0.5858	31	0.4561	49
Kheri	0.3097	70	0.6717	8	0.4545	50
Shahjahanpur	0.2947	71	0.6800	4	0.4489	51
Budaun	0.3978	44	0.5220	51	0.4475	52
Jalaun	0.3890	47	0.5345	45	0.4472	53
Kushi Nagar	0.4078	41	0.5055	55	0.4469	54
Etah	0.4698	28	0.3990	74	0.4415	55
Mau	0.3825	49	0.5219	52	0.4382	56
Basti	0.3741	53	0.5299	47	0.4364	57
Ghazipur	0.3985	43	0.4915	60	0.4357	58
Azamgarh	0.4022	42	0.4776	65	0.4324	59
Jaunpur	0.3711	54	0.5234	50	0.4320	60
Pratapgarh	0.3663	57	0.5282	48	0.4311	61
Ambedkar Nagar	0.3316	65	0.5780	32	0.4302	62
Siddharth Nagar	0.3144	68	0.6005	25	0.4289	63
Auraiya	0.3371	64	0.5637	36	0.4278	64
Shravasti	0.2808	72	0.6356	16	0.4227	65
Mainpuri	0.3232	66	0.5486	40	0.4134	66
Etawah	0.3619	58	0.4880	62	0.4123	67
Faizabad	0.3603	60	0.4878	63	0.4113	68
Unnao	0.3131	69	0.5402	43	0.4039	69
Kanpur Dehat	0.3188	67	0.5276	49	0.4023	70
Kaushambi	0.3443	63	0.4872	64	0.4014	71
Kannauj	0.3702	55	0.4303	72	0.3942	72
Bahraich	0.2450	74	0.6095	24	0.3908	73
Hardoi	0.2392	75	0.5365	44	0.3581	74
Amethi	0.2606	73	0.4746	67	0.3462	75

Districts wise rank and indices of sustainable food security and its components in Uttar Pradesh

District	Sustainable Food Availability Index		Sustainable Food Access Index		Food Utilization Index		Sustainable Food Security Index	
	Index value	Rank	Index value	Rank	Index value	Rank	Index value	Rank
Meerut	0.6334	37	0.7196	1	0.7434	7	0.6954	1
Bulandshahr	0.6516	24	0.6623	3	0.6295	23	0.6475	2
Muzaffarnagar	0.6295	38	0.6561	4	0.6435	22	0.6429	3
Hathras	0.6694	12	0.6052	10	0.6524	21	0.6412	4
Saharanpur	0.6052	46	0.6277	7	0.6587	19	0.6298	5
Agra	0.5936	51	0.5942	11	0.7139	9	0.6291	6
Gautam Buddha Nagar	0.5837	52	0.6232	8	0.6715	15	0.6241	7
Deoria	0.6659	13	0.4913	33	0.7840	4	0.6233	8
Aligarh	0.6159	44	0.6177	9	0.6175	27	0.6170	9
Chandauli	0.7217	2	0.5582	15	0.5910	33	0.6161	10
Ballia	0.6490	26	0.4873	36	0.7830	5	0.6160	11
Gorakhpur	0.6413	32	0.5145	25	0.7308	8	0.6158	12
Baghpat	0.5646	58	0.6624	2	0.6199	26	0.6130	13
Firozabad	0.6173	43	0.5801	12	0.6163	28	0.6041	14
Azamgarh	0.6546	20	0.4324	59	0.8632	1	0.6001	15
Ghaziabad	0.4805	72	0.6428	5	0.6968	12	0.5915	16
Bijnor	0.6483	28	0.5756	13	0.5562	38	0.5909	17
Lucknow	0.5203	69	0.5087	29	0.8368	3	0.5902	18
Jalaun	0.5989	48	0.4472	53	0.7749	6	0.5773	19
Mau	0.6546	21	0.4382	56	0.7103	10	0.5750	20
Shamli	0.6362	35	0.5231	20	0.5602	37	0.5694	21
Ghazipur	0.6412	33	0.4357	58	0.6921	13	0.5661	22
Varanasi	0.5303	68	0.5015	31	0.6920	14	0.5634	23
Jhansi	0.5688	55	0.4728	42	0.6659	17	0.5582	24
Hapur	0.6616	16	0.4620	44	0.5809	34	0.5558	25
Jaunpur	0.6199	41	0.4320	60	0.6688	16	0.5532	26
Farrukhabad	0.5655	57	0.4856	39	0.6143	29	0.5499	27
Moradabad	0.6416	31	0.5567	16	0.4727	53	0.5484	28
Ambedkar Nagar	0.6581	18	0.4302	62	0.6027	32	0.5451	29
Kanpur Nagar	0.4327	74	0.4902	34	0.8587	2	0.5439	30
Mathura	0.5982	49	0.6365	6	0.4380	58	0.5429	31
Etah	0.6650	14	0.4415	55	0.5644	36	0.5414	32
Bareilly	0.6736	9	0.5115	26	0.4693	54	0.5386	33
Amroha	0.6529	23	0.5319	17	0.4625	55	0.5383	34
Auraiya	0.5777	53	0.4278	64	0.6598	18	0.5372	35

Mainpuri	0.6539	22	0.4134	66	0.6086	30	0.5365	36
Sant Kabir Nagar	0.6603	17	0.4658	43	0.5176	41	0.5364	37
Kannauj	0.6155	45	0.3942	72	0.6558	20	0.5276	38
Etawah	0.5457	63	0.4123	67	0.6992	11	0.5275	39
Banda	0.5130	70	0.5235	19	0.5433	39	0.5263	40
Faizabad	0.6186	42	0.4113	68	0.6046	31	0.5262	41
Sultanpur	0.6250	40	0.4561	49	0.5215	40	0.5254	42
Allahabad	0.5354	65	0.5248	18	0.5113	44	0.5237	43
Pilibhit	0.7001	6	0.5085	30	0.4258	60	0.5224	44
Sambhal	0.7123	4	0.4606	46	0.4568	56	0.5205	45
Kushi Nagar	0.6732	10	0.4469	54	0.4895	48	0.5203	46
Shahjahanpur	0.6731	11	0.4489	51	0.4830	51	0.5187	47
Gonda	0.6554	19	0.4571	48	0.4810	52	0.5179	48
Bara Banki	0.6404	34	0.4609	45	0.4849	50	0.5178	49
Fatehpur	0.5490	62	0.4880	35	0.5085	46	0.5139	50
Rampur	0.6641	15	0.5110	27	0.4199	62	0.5134	51
Kheri	0.7079	5	0.4545	50	0.4451	57	0.5120	52
Hamirpur	0.4286	75	0.5173	23	0.6211	25	0.5105	53
Basti	0.6049	47	0.4364	57	0.5114	43	0.5085	54
Kasganj	0.7349	1	0.4811	40	0.4034	64	0.5069	55
Raebareli	0.5310	66	0.5011	32	0.4862	49	0.5054	56
Unnao	0.5767	54	0.4039	69	0.5755	35	0.5044	57
Budaun	0.6952	7	0.4475	52	0.4266	59	0.4986	58
Pratapgarh	0.5670	56	0.4311	61	0.5096	45	0.4962	59
Lalitpur	0.6349	36	0.5616	14	0.3716	67	0.4962	60
Kanpur Dehat	0.4995	71	0.4023	70	0.6268	24	0.4932	61
Sitapur	0.6450	29	0.4592	47	0.4214	61	0.4917	62
Mahoba	0.5545	61	0.5182	21	0.3960	65	0.4793	63
Mirzapur	0.5554	59	0.5158	24	0.3903	66	0.4761	64
Hardoi	0.6291	39	0.3581	74	0.5063	47	0.4719	65
Amethi	0.6508	25	0.3462	75	0.5162	42	0.4716	66
Siddharth Nagar	0.6923	8	0.4289	63	0.3639	68	0.4598	67
Chitrakoot	0.4636	73	0.4866	38	0.4132	63	0.4523	68
Sonbhadra	0.5309	67	0.5176	22	0.3530	69	0.4512	69
Maharajganj	0.7183	3	0.4867	37	0.2681	74	0.4180	70
Sant Ravidas Nagar	0.5362	64	0.5088	28	0.2859	71	0.4094	71
Kaushambi	0.5553	60	0.4014	71	0.3201	70	0.4045	72
Balrampur	0.5951	50	0.4759	41	0.2687	73	0.3999	73
Bahraich	0.6487	27	0.3908	73	0.2816	72	0.3921	74
Shravasti	0.6427	30	0.4227	65	0.0677	75	0.1604	75

VITA

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