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EFFECT OF CLIMATE CHANGE AND ASSOCIATED FACTORS ON THE PRODUCTION AND PRODUCTIVITY OF WHEAT (*Triticum aestivum L.*) OVER LAST 25 YEARS IN THE TERAI REGION OF NEPAL

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Abstract

A study on the effect of climate change and associated factors on the production and productivity of wheat (*Triticum aestivum L.*) over last 25 years in the Terai region of Nepal was conducted. Three major wheat growing districts of Nepal (Kanchanpur, Rupandehi and Dhanusha) were focused. Climate and wheat management data were deployed. Farmers' feedback was taken through a set of semi-structured questionnaire followed by one day workshop cum seminar. Focus Group Discussion (FGD) was also conducted in the field. Comparison over 25 years showed that rainfall during wheat season declined significantly while maximum temperature increased by over 1^0C. Mean minimum temperature showed slight decline. Farmers' interaction indicated that growth period of wheat appeared to reduce over years, while new diseases/races and weeds have emerged. This led to increase in use of chemical pesticides. Use of inputs such as chemical fertilizers increased significantly leading to increased production cost by many folds. Despite limitations, wheat farming area and production has increased significantly in the past 25 years. The major issues for farmers were found to be a deficit of inorganic fertilizers, insufficient supply of quality seeds and an unsystematic market. The coping mechanism for climate change in wheat farming in all the three districts was not applied due to lack of knowledge, facilities and access to improved technologies. The farmers expected advanced technological know-how along with other facilities for climate resilient wheat farming.

Keywords: Wheat production, diseases, weeds, climate change, climate resilience

Introduction

Agriculture is the major source of national economy in Nepal and 65.60% of whole population is dependent upon it **(MOAC, 2012).** The main agricultural crops are rice, wheat and maize. Among them wheat is the third most important cereal crop in terms of area and production. Wheat was a minor cereal until early 1960s'. The population growth, food insecurity and development of high yielding new varieties led to massive wheat production in the world and the Nepal. At present wheat is grown in 754,474 ha with total production of 18,83,147 mt and the productivity is 2,496 Kg ha^{-1}. It occupies 23% of total cereal area and contributes 22.5% of the total cereal production in the country **(MOAD, 2012).** So far around 40 wheat varieties have been released in Nepal. The most popular varieties released for Terai region are Gautam, NL 297, Bhrikuti and Vijay. The new varieties like BL 3623, 3629, NL 1008 are in the pipe line **(NWRP, 2013/14).**

Wheat is cultivated in whole of south Asia with sowing time varying from early (October) to late (December). In the context of Nepal, late cultivation of wheat in the Terai region is very common mainly due to late rice harvest caused by longer duration varieties of rice **(Pokhrel et al., 2011).** Rice-wheat cropping system is one of the most important cropping system in Nepal with high significance for food security. However, lack of irrigation water is causing serious problem in sustaining this cropping system. Water scarcity, which is already a serious constraint in south Asian farming systems **(Xiaoyun et al., 2011),** may become more acute with climate change, and may lead to food insecurity **(Kang et al., 2009).** This may get exasperated with global warming. One of the climate models has shown that the adaptation measures necessary to mitigate the potential impacts of climate change could be adjustments in the sowing time and genotype selection **(Waffa and Benoit, 2015).** Identification of terminal heat stress tolerant wheat genotypes through stress indices is one of the appropriate methods **(Puri et al., 2015).** Different strategies for climate resilient crop farming in Nepal have been proposed but the adequate achievements are not being obtained **(Shrestha et al., 2013).** Recently, National Wheat Research Program, Nepal in collaboration with International Maize and Wheat Improvement Center(CIMMYT), has identified early wheat genotypes with low grain filling duration such as BL 3978 that are able to escape the terminal heat stress **(Puri and Gautam, 2015).**

In Nepal, wheat is grown under various types of soils and climatic conditions. Climatic factors like rainfall, humidity and temperature strongly affect the growth and productivity of wheat **(NARC, 2010).** In addition, managing diseases like rusts (black, brown and yellow), powdery mildew, loose smut and spot blotch is important for successful wheat farming in Nepal **(NWRP, 2011)**. National Wheat Research Program (NWRP) of Nepal is carrying out research to develop and disseminate improved varieties of wheat for disease resistance (like stem rusts-Ug99, leaf and yellow rusts) **(Joshi et al., 2011)**. In the last five years, NWRP has released Ug99 resistant wheat genotypes namely, Vijay, Tilottama and Danphe. However, a proper study on the effects of climate change on wheat farming especially in Terai region of Nepal is still lacking. Future planning to increase wheat production in Nepal should give due consideration to climate change as the country is already facing the effects of global warming **(Nayava et al., 2009).**

The main objective of this study was to find out the effects of climate change and other associated factors on production and productivity of wheat in last 25 years in the Terai region of Nepal. The study also aimed to find out the methods adopted for climate resilient wheat farming by the farmers.

Materials and methods

Three important wheat growing districts of Nepal - Kanchanpur, Rupandehi and Dhanusha were selected as study area. These districts representing the potential wheat farming area of the Terai region of Nepal lie in the far western, western and central development region of Nepal (Fig. 1).

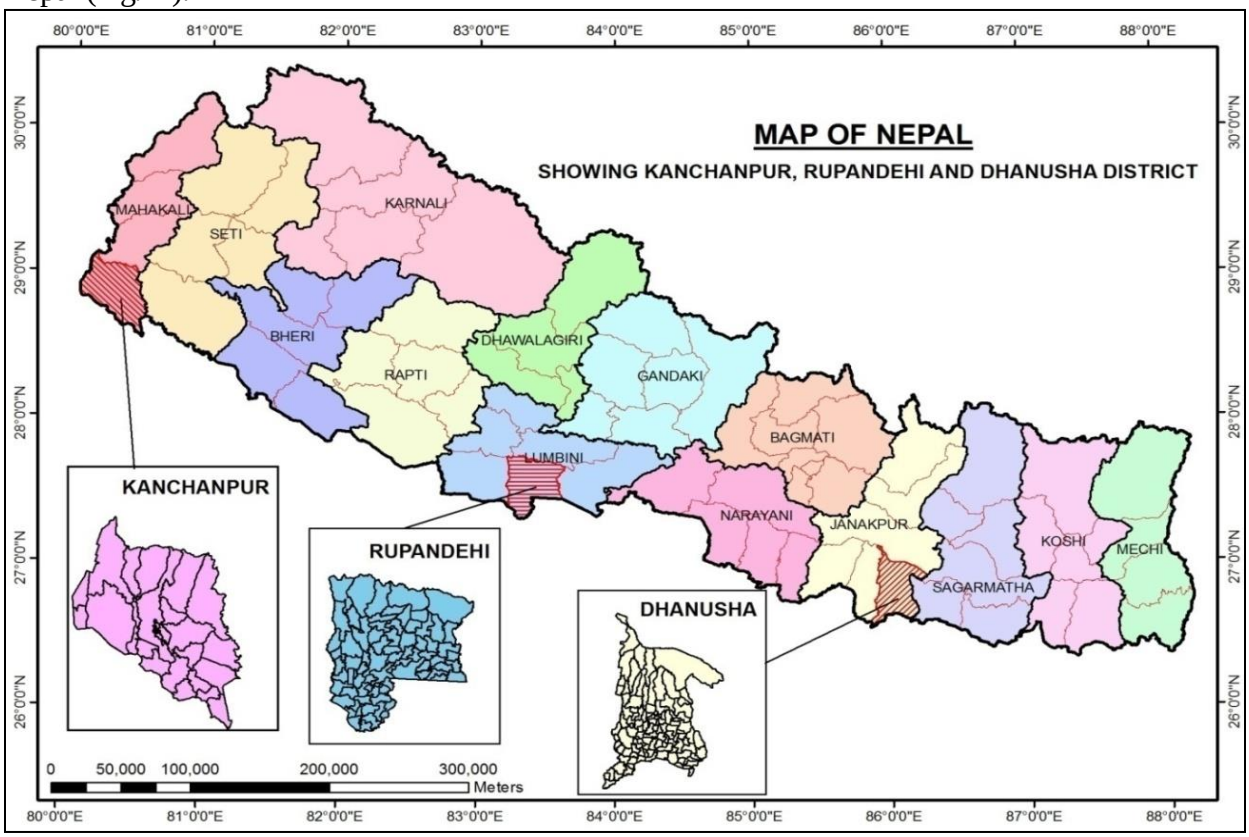

Fig. 1: Location of the three districts used for the study (Source: DWIDP, 2015)

Data on climate parameters (rainfall, minimum and maximum temperature) data over 25 years (1986-2010) was collected from Department of Hydrology and Meteorology (DHM), Nepal. For farmers' feedback, a set of semi-structured questionnaire including questions on a range of issues (sowing time, germination period, irrigations required, use of chemical fertilizer, harvesting time, new diseases, weeds, etc.) was prepared to investigate the trend and effect of climate and associated factors on wheat farming. Three hundred and ninety three farmers (131 farmers per district) were surveyed to fill up the questionnaire.

After field survey, one day interaction program entitled Farmer-Scientist Interaction Programme for Climate Resilient Wheat Farming was organized in each district. During the interaction programme major questions related to the change in wheat production and

practices over last 25 years, such as germination time, diseases, weeds, variety, use of compost and inorganic fertilizers, irrigation frequencies and yield were asked to the participants. In each meeting, the participants were divided into three sub-groups and were given a separate broad subject of question for discussion. After group discussion, group leaders from each group presented the findings of discussion. The presentations were refined after another round of in-depth discussion with the farmer participants. In each interaction program, wheat farming experts participated to facilitate discussion and to find out the actual problems induced by the climate change and related effects on wheat farming.

Results and discussion

Results

The targeted districts Kanchanpur, Rupandehi and Dhanusha consist of forest, farming and other usable land area (Fig. 2). The maximum forest area is in Kanchanpur while minimum in Dhanusha. Similarly, maximum farming area is in Rupandehi district and minimum in Kanchanpur.

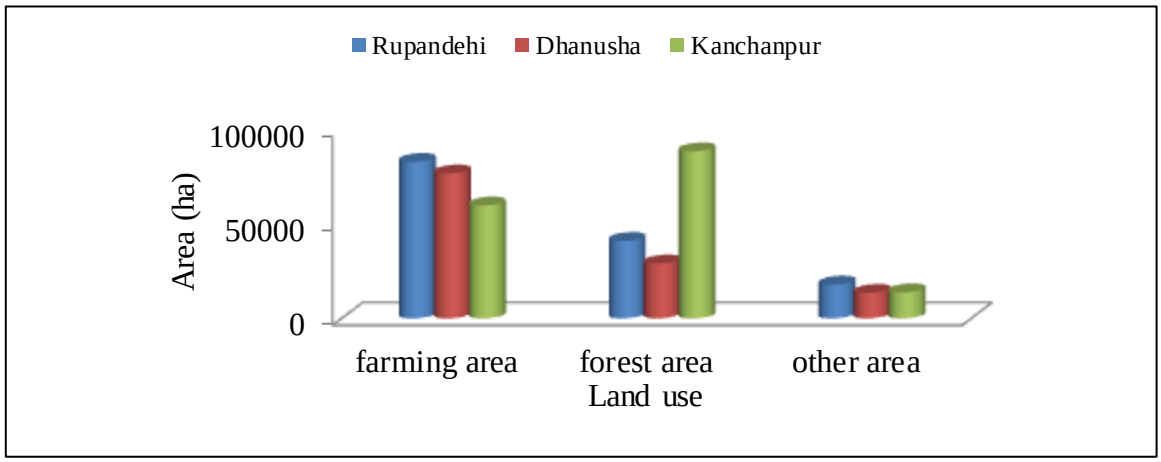

Fig. 2: Land use pattern of the study districts (Source: DADO, 2011; NARC, 2011)

The farming pattern in the three districts is presented in the Figure 3. Maximum wheat is produced in Dhanusha district while minimum in Rupandehi.

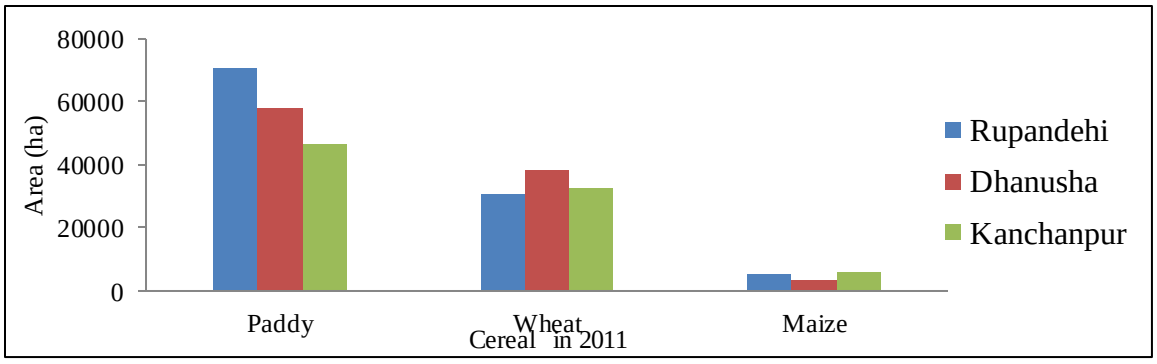

Fig. 3: Area of rice, wheat and maize of the study districts (Source: MOAC, 2012)

As the area of wheat production is different in three districts (Kanchanpur, Rupandehi and Dhanusha), the annual production rate is also different (Fig. 4). Wheat production was highest in the Dhanusha while Kanchanpur showed the least. The reason behind this could be due to lack of irrigation facilities, technical support, improved seeds and chemical fertilizers. It can also be due to the occurrence of rain at the late season as reported in an earlier study on wheat at Bhairahawa concluding that late rains have reduced wheat yield **(Bhandari, 2011)**.

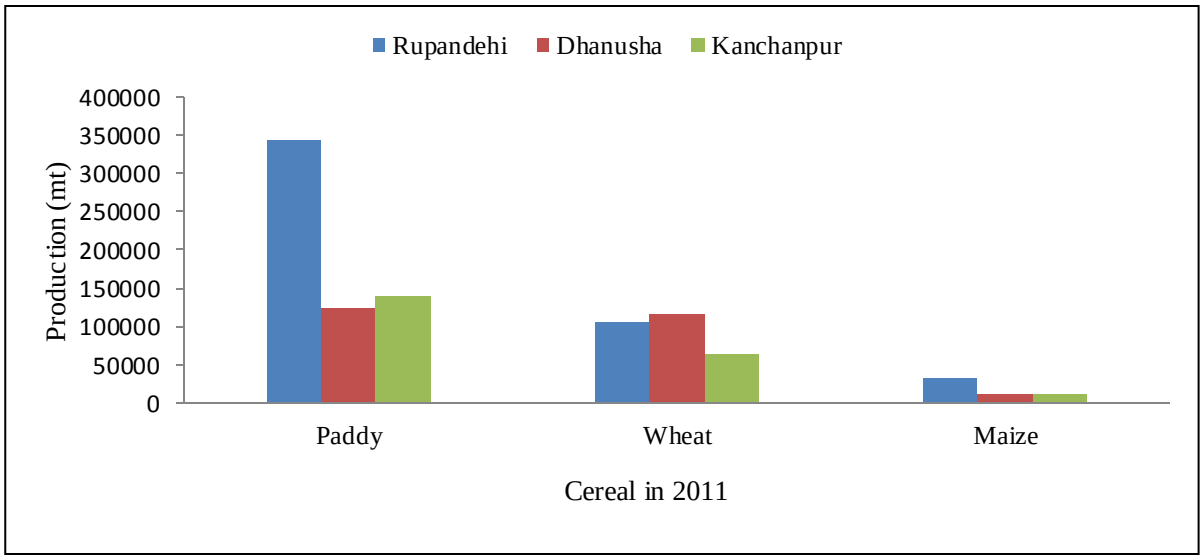

Fig. 4: **Total rice, wheat and maize production in the study area in 2011 (Source: MOAC, 2012)**

Despite management issues and other problems, wheat productivity trend showed a constant growth in all the three districts (Fig. 5). Of these Rupandehi district showed the highest increasing trend of wheat production.

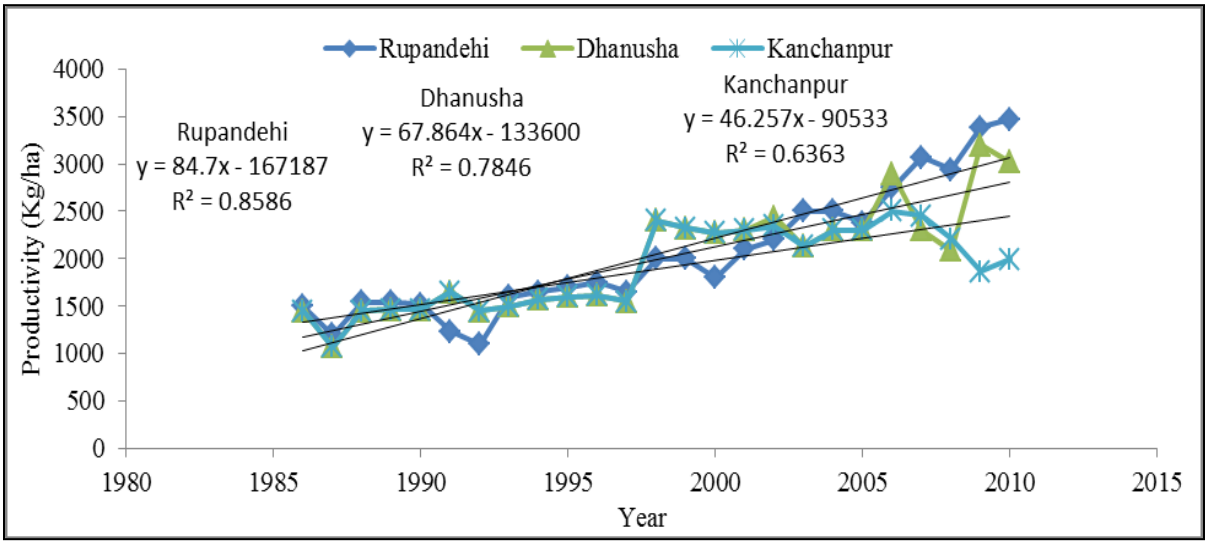

Fig. 5: **Trend of wheat productivity in the study districts (Source: MOAC, 2012)**

Climate parameters

Rainfall is one of the important indicators of climate change. The rainfall pattern of the study area during wheat crop season is presented in Figure 6. The rainfall pattern over last twenty five years showed a decreasing trend. This trend was more vivid in Rupandehi and Dhanusha.

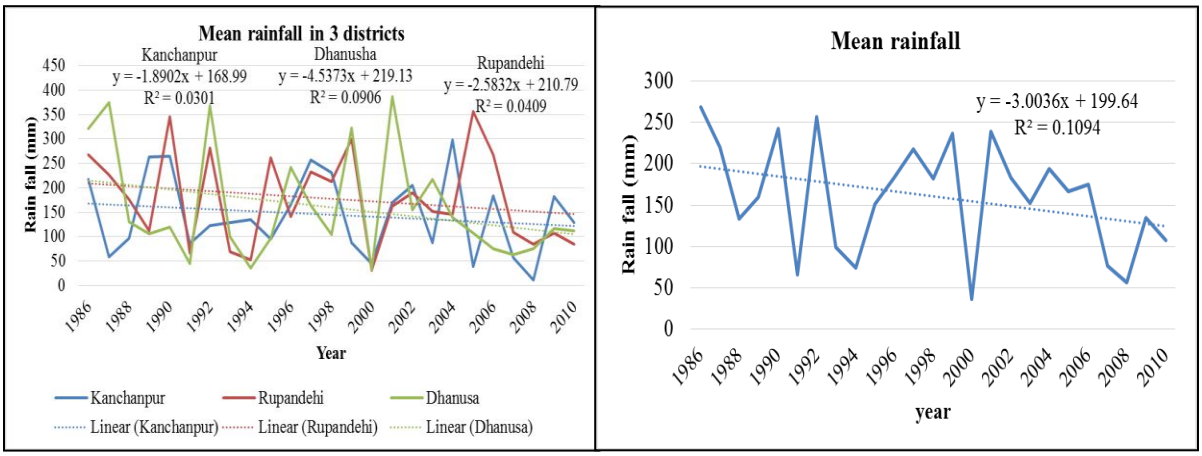

Fig. 6: **Rainfall pattern of the three study districts during wheat crop season (October to April) over a span of 25 years (Source: DHM, 2012)**

Temperature is one of the most important factors which affects wheat production and is considered a crucial parameter to judge the climate change. In fact global warming is judged based on trend of mean temperature over years. The mean minimum and maximum temperature of the study area in last 25 years is presented in Figure 7 and 8, respectively. The minimum temperature was found slightly decreasing over years while maximum temperature increased to more than 1^0C over 25 years.

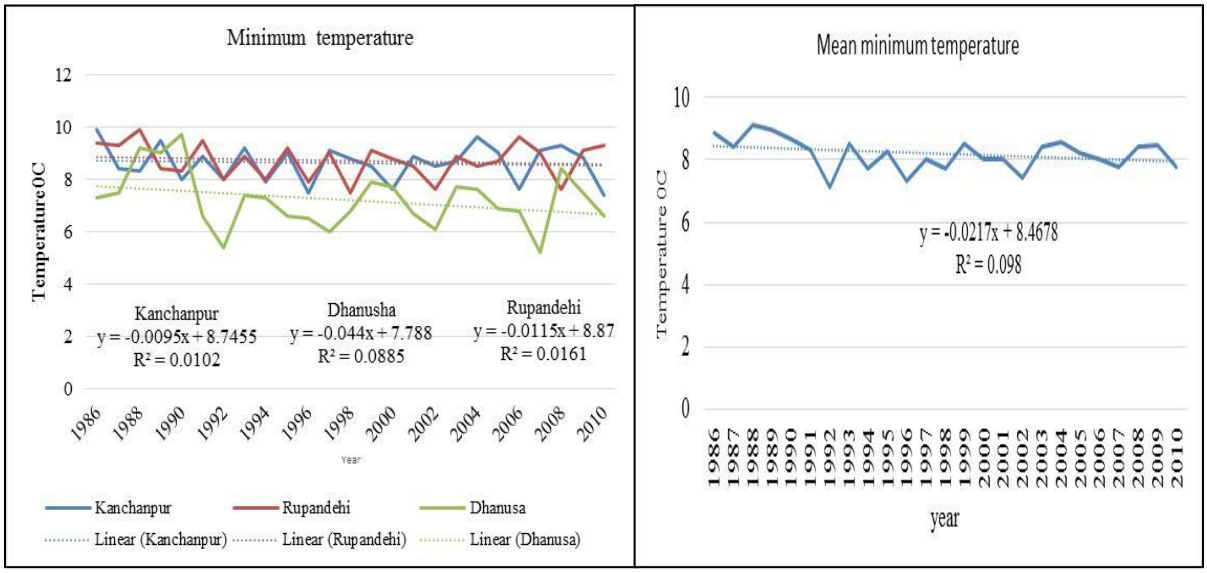

Fig. 7: **Minimum temperature pattern of the three study districts during wheat crop season (October to April) over a span of 25 years (Source: DHM, 2012)**

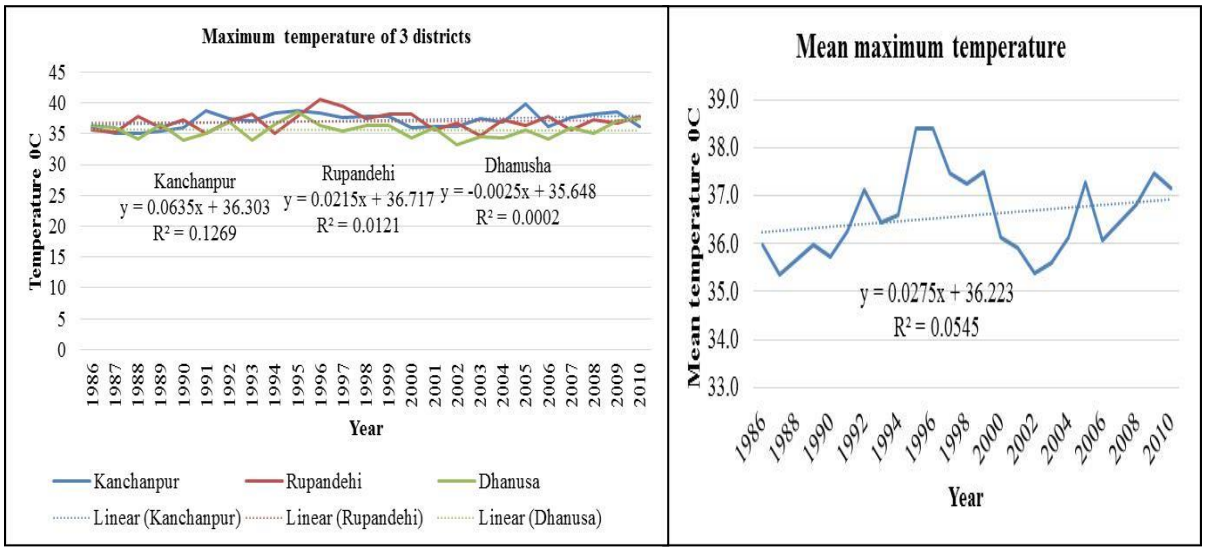

Fig. 8: Maximum temperature pattern of the three study districts during wheat crop season (October to April) over a span of 25 years (Source: DHM, 2012)

Perception of farmers on wheat farming

Almost all the farmers of Nepal give major priority to rice production than to wheat as they consider rice as a safer crop due to abundant monsoon rains. They grow wheat after harvesting the rice anytime between middle of October to the end of December. Compared to the past 25 years, the area under wheat farming, its production and use of fertilizer and irrigation facilities have increased in the entire three districts investigated (Table 1, 2 and 3).

The details of comparison of wheat farming of Kanchanpur district which lies in the far western development region of Nepal is presented in Table 1.

Table 1: Comparison of wheat farming and associated components of 25 years ago and at present in Kanchanpur district of Nepal

Activities	25 years ago	Now
Sowing time	End of December (Second week of Pouush)	End of November (Second week of Manghsir)
Name of Variety	Dhaniya, local wheat like Rato/Seto. Improved wheat varieties: RR21, UP262, NL 297.	Bhrikuti, Gautam, NL 297, NL 251, Vijay, Aditya, BL 1012, UP 262, UP343.
Type of seed	Local	Improved
Seed germination period	7-10 days	4-7 days
Irrigation	Most of wheat farming was dependent on rainfall. Only some farmers (10%) used to irrigate one time.	The survey showed that about 60 % farmers irrigate 2-3 times.
Diseases and insect-pests in	Loose smut, black rust, leaf rust	Loose smut, black rust, yellow rust,

wheat		leaf rust, foliar blight, aphids
Weeds in wheat	*Phalaris minor* (Ragate Jhar), *Chenopodium album*(Bethuwa),*Vicia spp.* (Ankara), *Cyperus spp.*(Mothe),*Runex spp*.(Ban Palaki), *Avena ludoviciana* (JaujastoJhar), *Cynodon dactylon* (Dubo)	*Phalaris minor* (Ragate Jhar), *Chenopodium album*(Bethuwa),*Vicia spp.* (Ankara), *Cyperus spp.*(Mothe), *Runex spp*. (Ban Palaki), *Avena ludoviciana* (JaujastoJhar), *Cynodon dactylon* (Dubo), *Parthenium*
Use of organic manure	The survey showed that organic manure was used 20 quintal per Bigha (about 70%).	Most of the farmers use inorganic fertilizers. Only 5 quintal per Bigha (about 25 % use organic manure).
Use of Chemical fertilizer -DAP -Urea -Potash	Farmers did not use chemical fertilizer (0%).	Chemical fertilizers are used very commonly. -50 kg/bigha (DAP) -75 kg /bigha(Urea) -25kg/bigha (Potash) 1 bigha=6666.66 square meter
Use of chemical pesticide (Insecticides, fungicides, herbicides)	No use of chemical pesticides (0%).	Use of chemical pesticides increased by 80%
Harvesting period	130-150 days	110-130 days
Area of wheat farming	11250 ha	32250 ha
Productivity (Kg ha^1)	1450 Kg ha^{-1}	1992 Kg ha^{-1}
Cropping technology	Traditional	60 % Improved technology
Share of wheat	15 % of total cereal production	30 % of total cereal production
Use of wheat	Only for food	Food - 50%; Seed -10%; Sell-40%
Source: Field survey, 2012		

Rupandehi is located at the middle of the country and the total production of wheat in this district is next to rice. The comparison of past and present status of wheat production and associated components are presented in Table 2.

Table 2: Comparison of wheat farming and associated components of 25 years ago and at present in Rupandehi district, Nepal		
Activities	**25 years ago**	**Now**
Sowing time	End of December (Second week of Pouush)	End of November (First week of Manghsir)
Name of Variety	PBW-343, RR 21,UP262,	N L 297, Bhrikuti, Gautam, Vijay, Aditya
Type of seed	Local	Improved
Seed germination period	6-9 days	4-7 days
Irrigation	Most of wheat farming was dependent on rainfall. Only some farmers (10%) used to irrigate one time.	The survey showed that about 50 % farmers' irrigate 1-3 times.
Diseases and insect-pests in wheat	Loose smut, black rust, leaf rust	Loose smut, black rust, yellow rust, Leaf rust, leaf light, spot blotch, aphids
Weeds in wheat	*Phalaris minor* (Ragate Jhar), *Chenopodium album* (Bethuwa) *Vicia spp.* (Ankara), *Cyperus spp.*(Mothe), *Runex spp*.(Ban Palaki),	*Phalaris minor* (Ragate Jhar), *Chenopodium album* (Bethuwa), *Vicia spp.* (Ankara), *Cyperus spp.*(Mothe), *Runex spp*. (Ban Palaki), *Avena ludoviciana* (Jaujasto Jhar), *Cynodon dactylon* (Dubo), Bulbule, Jagato, KutliKosa; *Parthenium*
Use of organic manure	The survey showed that organic manure was used 15 quintal per Bigha (about 75% farmer used).	Most of the farmers use inorganic fertilizers. Only 5 quintal per Bigha (about 25 % use organic manure).
Use of Chemical fertilizer -DAP -Urea -Potash	Farmers did not use chemical fertilizer (0%).	Chemical fertilizers are used very commonly. -20 kg/bigha (DAP) -75 kg /bigha (Urea) -25 kg/bigha (Potash) 1 bigha = 6666.66 square meter
Use of chemical pesticide (Insecticides, fungicides & herbicides)	No use of chemical pesticides (0%)	Use of chemical pesticides is increasing by 80%
Harvesting period	135-150 days	110-130 days
Area of wheat farming	23550 ha	30500 ha
Productivity (Kg ha-^{1})	1500 Kg ha^{-1}	3472 Kg ha^{-1}
Cropping technology	Traditional	85 % Improved technology
Share of wheat	15 % of total cereal production	22 % of total cereal production

Use of wheat	Only for food	Food- 30%; Seed -5%; Sell- 60%
Source: Field survey, 2012		

Dhanusha was the third study district. In this district, wheat production is placed in the second place after rice. The comparison of wheat production in this district with the past is presented in Table 3.

Table 3: Comparison of wheat farming and associated components of 25 years ago and at present in Dhanusha district, Nepal

Activities	25 Years Ago	Now
Sowing time	End of December (Second week of Pouush)	End of November (First week of Manghsir)
Name of Variety	Sonalika, RR 21, UP262, N L 297.	Bhrikuti, Gautam, Vijay, Achyut, Gaura.
Type of seed	Local	Improved
Seed germination period	7-10 days	5-7 days
Irrigation	Most of wheat farming was dependent on rainfall. Only some farmers (10%) used to irrigate one time.	The survey showed that about 50 % farmers irrigate 2 times. (20-25 days after wheat sowing)
Diseases and insect-pests in wheat	Loose smut, black rust, leaf rust, black rust	Loose smut, black rust, yellow rust, Leaf rust, foliar blight
Weeds in wheat	*Phalaris minor* (Ragate Jhar), *Chenopodium album* (Bethuwa) *Vicia spp*. (Ankara), *Cyperus spp*. (Mothe), *Runex spp*. (Ban Palaki), *Avena ludoviciana* (Jaujasto Jhar), *Cynodon dactylon* (Dubo).	*Phalaris minor* (Ragate Jhar), *Chenopodium album* (Bethuwa) *Vicia spp*. (Ankara), *Cyperus spp*.(Mothe), *Runex spp*.(Ban Palaki), *Avena ludoviciana* (JaujastoJhar), *Cynodon dactylon* (Dubo), *Parthenium*
Use of organic manure	The survey showed that organic manure was used 20 quintal per Bigha (about 70%).	Most of the farmers use inorganic fertilizers. Only 5 quintal per Bigha (about 25 % use organic manure).
Use of Chemical fertilizer -DAP -Urea -Potash -Zink	Farmers did not use chemical fertilizer (0%)	Farmers did not use chemical fertilizer (0%) -100 kg/bigha (DAP) -40 kg /bigha(Urea) -40kg/bigha (Potash) -20 kg/bigha (Zinc) 1 bigha = 6666.66 square meter
Use of chemical pesticide (Insecticides, fungicides & herbicides	No use of chemical pesticides (0%)	Use of chemical pesticides is increasing by 75%

Harvesting period	130-150 days	110-125 days
Area of wheat farming	11250 ha	38450 ha
Productivity (Kg ha^{-1})	1450 Kg ha^{-1}	3020 Kg ha^{-1}
Cropping technology	Traditional	80 % Improved technology
Share of wheat	15 % of total cereal production	46 % of total cereal production
Use of wheat	Only for food	Food - 60%; Seed -5%; Sell- 35%
Source: Field survey, 2012		

Insect-pest and diseases

Rusts continue to be important in Terai. However, yellow rust is becoming more frequent than earlier. Foliar blight was not important 25 years ago, but now is a significant disease. Loose smut was a minor problem and is still observed in farmers' fields. Black rust is a globally important disease but so far is not perceived as a threat in the Terai region of Nepal.

Discussion

The present study showed that the trend of wheat adoption has been increasing. This has increased the production as well as productivity of wheat with the advancement of new varieties, irrigation facility, crop production technology and market expansion. Wheat production in all three districts increased many folds as compared to the past 25 years. Climatic factors like rainfall and temperature strongly affect the growth, productivity, and carbon emission **(NARC, 2010).** Global warming is gradually becoming a matter of great concern for every country. Its effect in Nepal was also visible in this study in the form of reduction in rainfall and increase in mean maximum temperature over last 25 years in the districts investigated. Since terminal heat stress causes significant loss to wheat yield, due attention should be given to the likely effects of increase in temperature during the maturity period of wheat.. Combined with low rainfall, increased maximum temperature can cause deadly effect.

It was observed that the germination and the harvesting period of wheat have decreased as compared to the past. This could be due to development and adoption of early maturing varieties and also one of the effects of climate change and early hot western winds. The effect of decreased period available for wheat crop may have effect on the livelihood of the poor people in the country if there is further shrinkage of growth period of wheat and other crops. And the solution for this problem ultimately seeks an adaptation strategy very urgently **(NARC, 2010).** In Mexico, a study showed that both climatic and non-climatic factors such as government policy and facilities to be provided in time to the farmers are important to sustain wheat yields **(David et al., 2005).**

The present study showed that farmers are experiencing new diseases, pests and weeds in wheat farming. The new diseases being observed in these days are yellow rust and foliar blight. The reason behind the increase in new diseases could be the pathogens adoption to new environments. Yellow rust is increasing in Nepal in epidemic form, mainly in the hills

(Sharma, 2008). However, it is also appearing in the Terai region bordering hills. The probable cause behind it could be decrease in mean minimum temperature and pathogens own ability to get adjusted to different temperature range. Foliar blight and leaf rust are more harmful in the eastern Terai region of Nepal **(Dangal et al., 2015).** Other changes like appearance of new weeds such as *Parthenium* sp. and aphids were also observed. The use of inorganic fertilizers like DAP, urea and potash have also increased a lot since past decades. During survey, farmers reported that the use of organic manure is only 25 %.

The problem of climate change and its effects on wheat farming have been experienced by the farmers of Kanchanpur, Rupandehi and Dhanusha districts. However, they don't have access to much adaptation technologies. Often seeds and fertilizers become scarce. Lack of awareness among farmers on new technologies also exist significantly **(Bhandari, 2015).** For better farming, seed plays an important role and is the living input having the genetic potential of production **(Joshi et al., 2011).** If the farmers have not access to appropriate seeds, the increase in yield could be difficult. The problem of poor quality seeds in Kanchanpur, Rupandehi and Dhanusha district is very common. The farmers also suffer from the financial crisis. Furthermore, market is not very secure. In short, to cope with the climatic change, a prudent management related to wheat farming is needed for the benefit of the farmers. However, one of the major problems in the Terai region is to assure an effective way of supplying inputs matching with the demand.

It was observed that mechanization has increased over past two decades and this is benefitting farmers. They used more labor per hectare in the past but now-a-days mechanization has reduced this by more use of tractor, combined harvester and other machineries. According to the respondent during field survey 50% machine and 50% labor is used for wheat farming in the Terai region of Nepal.

In 1960's the productivity was only 1.5 Mt ha^{-1} **(NARC, 2010).** Since then the area and production has also increased. The productivity of the wheat increased significantly from 1.5 Mt ha^{-1} to 2.5 Mt ha^{-1} **(MOAD, 2014).** This was mainly due to the release of argonomically superior and adaptive wheat varieties by the national wheat research program in which collaboration with CIMMYT played a major role (NWRP, 2013/14). The irrigation was not in practice in the past. Most of wheat farming was based on the rain moisture. Due to increase in wheat production, the market has also expanded. Therefore, the farmers cultivate wheat in a wide range of area and sell about 60 % of their produce.

The study suggests that the farmers must develop a cooperative type of system. This will facilitate purchase of inputs in low cost and at the same time will give them bargaining power to sell their produce. Farmers need exposure to trainings, seminars and farmer-scientist interactions for awareness creation. There is a need to focus more on developing climate resilient wheat genotypes (like biotic and abiotic stress tolerant) and their faster dissemination. Use of participatory varietal selection which is one of the main seed dissemination strategies in Nepal **(Witcombe et al. 2001; Joshi et al., 2011)** can be deployed for benefitting small and marginal farmers.

Conclusion

The global warming is gradually becoming a matter of great concern for every country including Nepal. A trend of reduced rainfall and increase in mean maximum temperature during wheat cycle was observed over 25 years. The study showed that wheat area, production and the productivity has adequately increased in the study area. This increase happened due to advancement of breeding new climate resilient wheat varieties and making new seeds available to farmers, irrigation facility, technology and market expansion. On the other hand, farmers have experienced new diseases and weeds in wheat farming. The new diseases could be the effects of climate change. The use of inorganic fertilizers like DAP, Urea and Potash have also increased many folds while organic manure has gone down. Farmers demanded heat tolerant varieties and advanced technology along with other facilities for climate resilient wheat farming.

Acknowledgements

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