IMPACT OF ELEVATED CO_2 ON THE FOOD PRODUCTION OF NEPAL

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ABSTRACT

The three cereal crops rice, maize and wheat cover over 75% of the total food production of Nepal. All the three crops rice, maize and wheat showed increased yield with doubling the CO_2 level but also showed a declining tendency at the elevated temperature. Among the three crops, maize was the most affected by the rise in temperature although increased CO_2 level could increase the crop yield. The Terai plains and the hills of Nepal were more affected. The mountains showed favorable tendency.

INTRODUCTION

Agriculture is the mainstay of Nepal which commands nearly 40 percent of the total Gross Domestic Product. Rice, maize and wheat are the major cereal crops which command over 75 % of the total food production (ABP&SD, 2003). The agriculture oerspective plan (APP) was drawn ten years back to boost the agriculture production in Nepal (APROSC and JM Assoc., 1995). Effects of global warming might adversely affect the crop productivity particularly in the tropical and sub-tropical regions of the world (Parry and Swaminathan, 1992; Rao, 1994; Saseendran et al., 2000). IRRI scientists report that rice yields decline with higher night temperature from the global warming (Peng, 2004), a matter of concern that could jeopardize the food security of a country. This study was carried out to under-

METHODOLOGY

Crop :
Rice (*Oriyza sativa*)
Wheat (*Triticum astevum*)
Maize (*Zea mays*)

Model :
CERES-Rice,
CERES-Wheat
CERES-Maize (DSSAT, 1998)

Ecology:
1. Terai plain (60-600m)
2. Hill (600-2000m)
3. Mountain (2000-4000m)

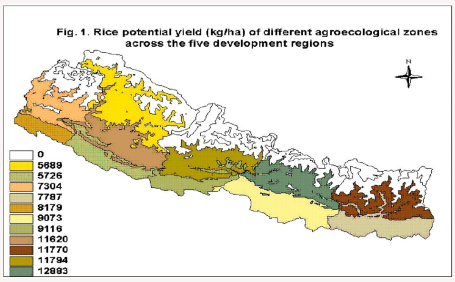
Yield Analysis :
1.Potential yield
2. Actual yield (Given or recommended)

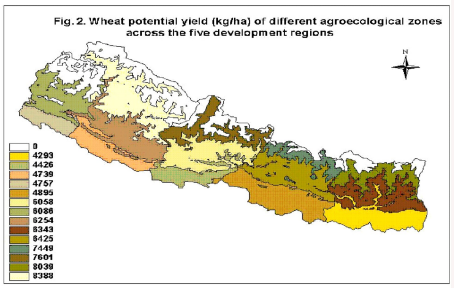
Climate Scenario:
1. Ambient;
2. Ambient + 250 ppm CO_2;
3. Ambient + 250 ppm CO_2 +1oC; Ambient + 250 ppm CO_2 + 2 oC; Ambient + 250 ppm CO_2 + 4 oC;
4. Ambient + 250 ppm CO_2 + 20% rain; Ambient + 250 ppm CO_2 + 1 oC + 20% rain; Ambient + 250 ppm CO_2 + 2 oC + 20% rain; Ambient + 250 ppm CO_2 + 4 oC + 20% rain.

Food Production Scenario:
1.Business as Usual
2.Agriculture Perspective Plan (APP)
3.Climate Change

Crop : Rice, wheat, maize, millet and potato

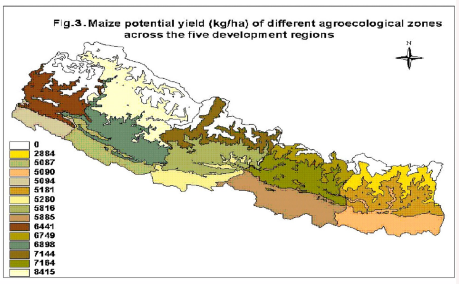
The study delineates three ecological belts: Terai plain (60 to 600 m), hill (600 to 2000 m), and mountain (2000 to 4000 m) above sea level. Beyond 4000 m are excluded because that is considered not being suitable for crop cultivation. Site specific estimates of yield changes were aggregated to each ecological belt. The ecological delineation could explain how the CO_2 rise could affect the crop productivity under different climatic zones. For the average potential yield to be shown in the map of Nepal each ecological region was divided into five administrative regions (Fig. 1, 2 and 3). However, crop yields, both potential and actual (a given condition) were measured in percent change from the Ambient (Fig. 4). In the absence of the clear-cut future scenario, the analysis is based on the incremental climate scenario rather than the predicted scenario.





RESULTS AND DISCUSSION

The potential yields of rice, wheat and maize are estimated across three ecological belts and five development regions. The variations of potential yields were observed in all three crops which ranged between 5.69 to 12.88 t/ha in rice (Fig. 1), between 4.29 to 8.39 t/ha in wheat (Fig. 2) and between 2.88 to 8.42 t/ha in maize (Fig. 3). The rice potential yield was observed more in the mid hill followed by Terai plain and least in the mountain. Whereas, the wheat potential yield were more to be in the mountain and least in the Terai plain. The maize potential yield showed somewhat mixed trend, more in the mid hill as well as the mountain but less in the Terai plain. These crops have also shown tendency of performing better in the west than in the east which could be attributed to the higher solar radiation.



Impact

Rice

The rice actual yield increased by 9.5 % in the terai plain, 5.9 % in the hills and 16.6 % in the mountains under the double the CO_2 but dropped to 3.4 % in the Terai plain; continued to increase to 17.9 % in the hills and 36.1 % in the mountains at 4 ^{0}C rise (Fig. 4a1). The yield however dropped to -0.8 % in the Terai plains, 14.6 % in the hills but increased to 39.1 % in the mountains at 4 ^{0}C rise and +20 % rain. The CO_2 increase had thus more positive impact on the rice yield in the mountains.The rice potential yield increased by 19.4 % in the Terai plain, 17.8 % in the mid hill and 18.9 % in the mountain under the double the CO_2. The yield however dropped to 4.9 % in the Terai plain, -4.5 % in the mid hill but increased to 20.8 % in the mountain at 4 ^{0}C rise (Fig. 4a2). The rice yield would thus be more adversely affected in the Terai plains and the hills but remained more favourable in the mountains. Although, the CO_2 had positive impact on the rice yield, adverse response to temperature was reflected in the plain and hill rice varieties. Additional rain tended to negate the yield in the plain, not much in the hill but again was found to be favorable in the mountain. The negative trend in the plain could also be explained by the cause of flooding which could jeopardize the rice yield.

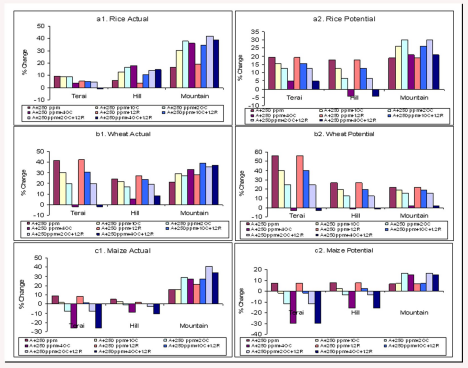


Fig. 4. Effect of elevated CO_2 (ppm) with rise of temperature on rice (a), wheat (b) and maize (c) yields in Nepal. (A= Ambient; R= Rainfall)

Wheat

The wheat actual yield rose to 41.5 % in the Terai plain, 24.4 % in the hill and 21.2 % in the mountain under the double the CO_2 (Fig. b1) . The wheat yield however continued to drop to -1.8% in the Terai plain and 5.3 % in the hill but increased to 33.3 % in the mountain at 4 ^{0}C rise. The wheat response therefore showed favourable impact in the mountains. Further the additional rains had also favorable impacts on the wheat yield with similar kinds of trends at all levels of temperature rise. The trends were also similar for the wheat potential yields. The wheat potential yield rose to 56% in the Terai plains, 26.6% in the hills and 21.8% in the mountains under the double the CO_2 concentration. But again, yield continued to decline to -3.5 % in the Terai plains, to -1. 6 % in the hills and to 1.9 % in the mountains (Fig. 4b2). Among the three regions, percent rise in the potential yields seemed to be higher in the Terai plains and lower in the mountains which were not the same while examining the actual yield. Thus the temperature rise conduced negative impact at 4 ^{0}C temperature rise in the Terai plains as well as the hills. The winter rains were expected to gain wheat yield in all the regions.

Maize

The effect of elevated CO_2 had little effect on raising maize yield. The maize actual yield under the double the CO_2 rose only by 9.0 % in the Terai plains, 4.9 % in the hills and 15.5 % in the mountains (Fig. 4C1). However, the maize yield continued to decline and reached -26.4 % in the Terai plain, -9.3 % in the hills but rose to 26.8 % in the mountains at 4 ^{0}C rise. The effect of additional rain did not vary much in the Terai plains and hills but was more favourable in the mountains. he maize potential yield rose again by 6.9 % in the Terai plains, 7.5 % in the hills and 6.7 % in the mountains. The potential yield continued to fall and reached -29.8 % in the Terai plains, -15.8 % in the hills but showed improved trend in the mountains at 4 ^{0}C temperature rise (Fig. 4C2). The maize yield improved little due to the elevated CO_2 but encountered more adverse effect due to the increased temperature particularly in the Terai plains and the hills. Therefore, changes in the maize yields, both actual and potential, improved consistently from Terai plains to the mountains. The response of CO_2 to these crops are more favourable in the mountains than in the Terai plains. The crop yield could further improved in the mountains. The maize and other C4 crops are more affected than the C3 crops

Table 1. Food projection under three different scenario from 2001 to 2075

Indicators	Projection by year						
	2001	2010	2020	2030	2050	2060	2075
Population	23155	27969	33550	39685	54205	62642	76611
Food production ('000 t)							
◆ Normal scenario	8839	10065	11645	13491	18180	21148	26602
◆ APP scenario	8839	12997	18486	-	-	-	-
◆ Climatic change scenario	8839	10046	11596	13399	17941	20791	25986
Edible food availability ('000 t)							
◆ Normal scenario	5802	6657	7766	9069	12409	14540	18484
◆ APP scenario	5802	8584	12335	-	-	-	-
◆ Climatic change scenario	5802	6640	7722	8986	12194	14221	17937
Per capita food availability (K-calorie/day)							
◆ Normal scenario	2369	2250	2188	2160	2164	2194	2275
◆ APP scenario	2369	2901	3475	-	-	-	-
◆ Climatic change scenario	2369	2244	2176	2140	2126	2146	2207
Per capita calorie requirement (K-calorie/day)	2130	2130	2130	2130	2130	2130	2130
Food sufficiency (%)							
◆ Normal scenario	111	106	103	101	102	103	107
◆ APP scenario	111	136	163	-	-	-	-
◆ Climatic change scenario	111	105	102	100	99	99	102

Food Projection

In case of APP, projection is done up to 2025 and for other scenario it has been done for the period up to 2075. Edible food availability has been calculated by adjusting for seeds, wastage, extraction, losses and edible share. The availability of the calories per person is calculated based on estimates of the edible food available in the country using conversion factors (MoAC, 1993). The population of Nepal was 23.16 million in 2001 which is estimated to grow to about 76 million with medium population growth unless some drastic measures are implemented (New Era and MoPE, 1995/96). The food production would jump from 8.8 million tons to 26.6 million tons under normal condition whereas, it would show different picture under the APP and climate change scenario (Table 1). Projections of calorie availability and the self-sufficiency ratio are based on the targeted growth rates for different plan periods (from 9th to 12th Plan) under APP and historical trend based on production growth function estimation. Climatic effect has been adjusted based on parameters obtained from the recent study. Under the three scenarios, food availability will be more under APP scenario and low under climatic effect adjusted scenario.

In 2001, for example, sufficiency ratio at the national level was 111% . In other words, the total population of the country was marginally self-sufficient from domestic production. But sufficiency level at district level varies greatly. Food sufficiency in the beginning will marginally go down but at later stage would show slight improvement due to the expected technological innovation and lower population growth.

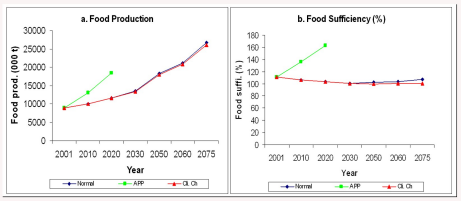


Fig. 5. Food production (a) and sufficiency trends (b) under different scenarios

CONCLUSION

The projections show that Nepal will be a nation of significant agricultural surplus if the APP production targets are achieved. There will be marginal surplus under normal scenario but will be barely meeting the requirement under the climatic change scenario when the CO_2 level is expected to double. If climatic effect is really considered to happen, the level of difficulties on attaining food sufficiency in days ahead will be further more.

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