Climate Change and its Impact on Rice Yield

Krishna Prasad Rijal

Abstract: Monsoon patterns have been changing noticeably in recent years around the globe. These changes have tremendous effects on agriculture systems especially in the areas where rainfall is the precondition of agriculture. This paper will investigate monsoon patterns in Nepal and how they correlate with recorded rice yields. The results were analyzed and cross-checked with AquaCrop, a crop water productivity model.

The findings indicate that the Nepal's monsoon patterns do not follow a definitive trend. Parameters such as onset and withdrawal dates, duration and distribution are quite unpredictable. The patterns, however, do have direct impact on national average rice yields, but that effect has turned less sensitive in recent years.

The findings suggest that though monsoon has vital role on rice production in Nepal, where agriculture systems depend primarily on rainfall, more research is required to predict more accurately and precisely the production functions and relationships to yield. The better we understand this relationship, the more we can compensate for adverse monsoon patterns through anticipatory deployment of ag-technologies and advanced management options. Furthermore, support from legislators will be required to move these ideas into practice.

Keywords: Climate change, monsoon, rice yield, AquaCrop model, Nepal

Introduction

The impact of climate change is immense in an agrarian country like Nepal. The temporal and spatial variation of climatic factors predominate agricultural productivity. Several irrigation systems in this country have been built to irrigate rice fields by utilizing the monsoon runoff because annual rainfall has become more and more unpredictable. Rice is the staple food for approximately 3.5 billion poor people around the world and accounts for one-fifth of the global calorie supply (Tripathi et al, 2012). More than 90% of production and consumption of rice is in Asia (Basnet, 2012). Rice is the leading cereal crop of Nepal in terms of production (4.46 million tons) and cultivation area (1.496 million hectares) (MOAC, 209). Rice production and sales provide 23% of the country's agricultural gross domestic product (GDP) and employs 65.6% of the population (MOAC, 2009), and rice provides 50% of the total calories requirement of the Nepalese people (MOAC, 2009) However, Nepalese rice productivity, about 3 tons per hectare, is very low compared with other rice-producing countries worldwide, and lower than most other South Asian countries (IRRI 2006). Rain-fed crops are crucial to feeding the growing global population. About 60% of global food comes from rain fed crops (Schultz et al., 2005). In Nepal, roughly two-thirds of the country's agricultural production requires rain fall, and if year round irrigation were possible, production would increase only by 50%, according to some estimates (WRS, 2002). As reported by the Nepal Agricultural Research Council (NARC) in 2007, more than 70% rice is grown under rain fed conditions, 9% in the uplands, and 21% under partially- or fully-irrigated conditions.

Therefore, climate is a primary determinant of agricultural productivity, especially in the case of developing countries like Nepal where agriculture is basically dependent on natural circumstances against the controlled environmental conditions in developed countries (Joshi et al. 2011). Monsoon is one of the prime factors governing the production of major crops in the country. Variability in the onset of the rainy season has led to variations in the start of the planting season of rain fed rice (Dahal, 2009). Monsoon rain affects rice yield in at least two ways: 1) The total amount and temporal variation of the monsoon rain affects soil moisture. 2) The date of monsoon onset affects the transplantation age of seedlings. Thus, erratic monsoon could hit the rain fed crops hard in terms of the yield. As weather patterns change, the economy of farmers, which depends on traditional subsistence-based agriculture, would become more vulnerable and difficult (Dahal, 2009).

Before the start of monsoon season each year, the topic of onset becomes a popular issue throughout Nepal. This event is important not only to farmers but also the agriculturists, economists, businessmen, and planners who have a great stake in matters of productivity. Monsoon onset draws attention because this event is critical to transplanting rice, the first crop of the country. If one were to observe only the media coverage of monsoon onset, it would appear that early monsoon is a cure-all for rice production. Here are a few headline examples:

- Late monsoon brings fear of food shortage in Nepal (AFP News, 2009)
- The monsoon arrives but too late (DFID, 2009)
- Emerging trend of change in rainfall patterns and its impact on traditional farming systems (Climate frontlines, 2009)
- Too little too late (Nepali Times, 2009)
- Late monsoon, fertilizer crunch to hit rice production (The Himalayan times, 2012)
- UN food agency: Poor monsoon likely to hit Nepal's paddy output (The Kathmandu Post, 2012a)

- Drop in paddy yield to hit Nepal›s GDP growth (The Kathmandu Post , 2012b)
- Nepal to face rice deficit of 900k tones this year (The Kathmandu Post , 2013)
- Monsoon and agriculture production in FY2013 in Nepal (Sapkota, 2013)

Our paper will provide insight on monsoon occurrence trends in Nepal and trace out the corresponding rice yield implications. In this process, we will test the hypothesis that early monsoon onset corresponds with higher rice yields.

Materials and Methods

We collected data on monsoon onset and withdrawal from the Department of Hydrology and Meteorology (DHM) of the Government of Nepal (GoN). Rice yield data was from Ministry of Agricultural (MoA) publications in 2012. In our study we compare the national average rice yields compared with simulated yields obtained through AquaCrop, a crop water productivity model developed by the FAO. AquaCrop uses input data sets on climate, crop, irrigation field management, and ground water table. Simulation was carried out for the years 2000-2009, keeping constant the crop, irrigation, field management and ground water table data and using actual recorded climatic data for that particular year. The climate data sets include rainfall, temperature, evaporations, and CO2. Among these, daily rainfall and temperature data were obtained from DHM. Evapotranspiration data was obtained from the database of LocClim software developed by FAO, which gives the average evapotranspiration over period of years for a particular location. CO2 data was adopted from the default data provided by AquaCrop.

For the simulation, we used a rain fed rice variety called Radha-7. It is widely used in Nepal and has a maturity period of 148 days. We assumed a plant density of 25,000 per hectare.

Since 15th Asadh[1] (normally 29th June) is celebrated as rice transplanting day in Nepal, we used that one month earlier (May 29) for the sowing of seeds (assuming 30 day old slips are transplanted). Rice transplanting depends on the monsoon onset date which is assumed in our as June 10 in Nepal. Thus, it takes 19 days from monsoon onset to the rice planting date on average. In our simulation, average rice planting date was calculated by adding 19 days to the actual monsoon arrival date in each year.

Among other inputs, irrigation options were taken as rain fed. Similarly, no specific field management data have been used, except a bund height of 25 cm in the terraced fields. Soil was taken as sandy loam. The ground water influence was ignored. This simulation used the climatic data from the Rampur station located in the Chitwan district of Nepal. This location was adopted because of data availability for that area and because the area had been previously validated for rice by the author (Rijal, 2012).

AquaCrop models were run for the years 2000 to 2009 keeping all the input data constant except the climatic data of temperature and rainfall. Among these two variables, temperature data didn't vary considerably over the period of analysis. In contrast, the monsoon rain events were found to be quite diverse from year to year.

Result and discussions

Monsoon trend

While monsoon onset is typically presumed as June 10 in Nepal, the past 45 years (1968-2012) show that more than 66% of onset have occurred past that date with a median onset date of June 13 (Figure 1). However, the trend of onset date is shifting earlier in recent years. Statistical analysis with data of 45 years showed that the mean monsoon duration is 103 days in that time period with a minimum duration of 72 days (1979) and maximum duration of 129 days (2008).

Monsoon occurrence events with their corresponding onset and withdrawal dates of the last 23 years (1990- 2012) are depicted in figure 2. This shows that the monsoon duration, onset, and withdrawal are random and do not appear to follow any definite trend.

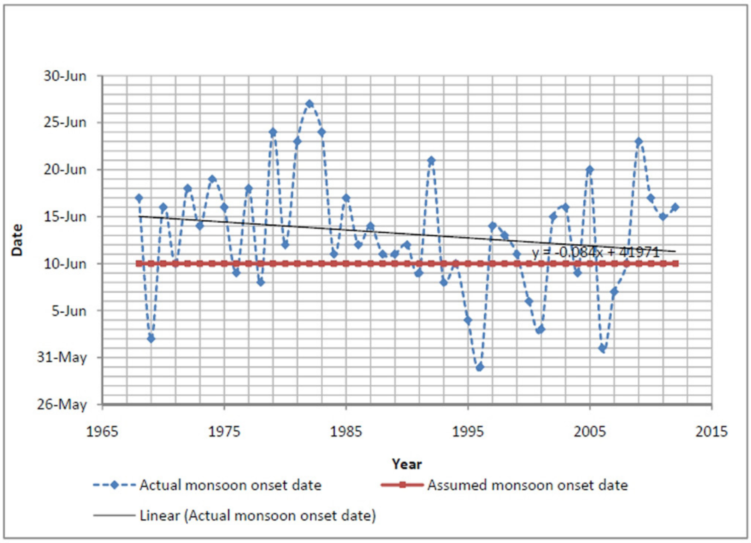

Figure 1: Monsoon Onset Trend, The monsoon onset date is shifting earlier. Though June 10 is assumed as monsoon onset date in Nepal, as of records till date, it has been found June 13 and also more than two third events have occurred beyond this date. Data source: Department of Hydrology and Meteorology, Government of Nepal.

Monsoon and actual yield

Various statistical analysis and graphical interpretations were carried out pertaining to monsoon events and national average rice yields. In the early years of our analysis, particularly before 2004, the relationship between monsoon onset date and yield seems inverse: the earlier the onset, the higher the yield. In later years, this relationship appears proportional except in for 2009. Figure 3 shows that the effect of monsoon onset date on yield is decreasing in recent years. This is a sensible conclusion as rice yields are dependent on many other factors than monsoon onset. It is possible that monsoon onset dependence on yield might have been decreased on recent years due to that compensated by one or many of the factors such as irrigation, improved seeds, timely availability of fertilizers, improved farming technologies etc.

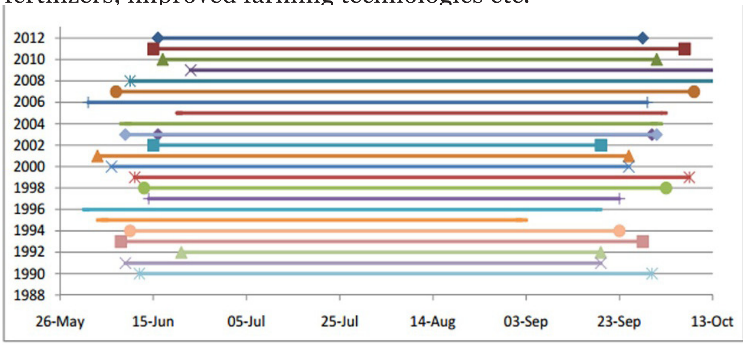

Figure 2: Monsoon Occurrence events. The monsoon occurrence events have not been following a definite trend on its onset, duration and the withdrawal.

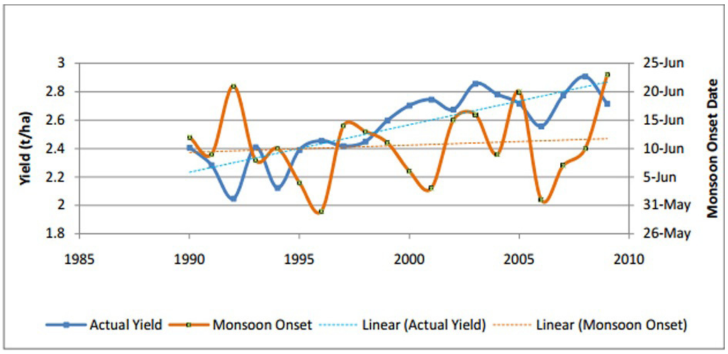

Figure 3: National average rice yield on the backdrop of monsoon onset date. In the earlier years, the national average rice yield has significant dependence on monsoon onset date, however in the recent years the nexus has broken to some extent.

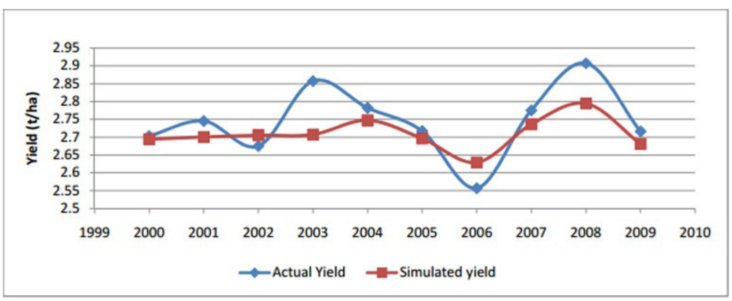

Figure 4: Comparison of recorded national average rice yield and simulated yield using AquaCrop. The simulated yield variation is only the reflection of climatic inputs (temperature and rainfall).

We conducted some correlation studies on actual yield and rainfall parameters. The actual yield and total rainfall amount during the crop period were slightly correlated (r = 0.26). The correlation was found weak because the monsoon rain amount was quite sufficient for the required soil moisture to the crop. This finding agrees with results from other recent experiments on water saving technologies (WSTs), which have demonstrated that rice doesn't need continuous submergence for high yield (Belder et at.,2004, Tuong and Bhuiyan, 1999, Singh et al., 2001, Arora et al., 2006, Anbumozhi et al.,1998, Zeng et al.,2003, Dunn and Gaydon, 2011, Tuong and Boman, 2003, Yang et al., 2012, Mahajan et al., 2009, Choudhury et al., 2007, Arora, 2006, Pirmoradian et al., 2004, Bouman and Tuong, 2000, Dawe, 2005, Tabbal et al., 2002, Bouman et al., 2007, Humphreys, E.,2005).

The average actual yield was found slightly negatively correlated to the skewed temporal distribution of rainfall (r = -0.06) during the crop period. Obviously, the skewed temporal distribution adversely affects the yield. The feebler correlation (r = -0.06) between the time gap of successive rainfall events and rice yield is in agreement with Rijal (2012) which has shown that the soil moisture application interval of less than 10 days for growing rice have no noticeable detrimental effect on the rice yield.

Simulation result

The crop growth simulation carried out in the climatic environment of Chitwan district of Nepal closely resembled the national average yields (Figure 4). The recorded national average yield and simulated yield over the period of analysis (2000 to 2009) strongly correlated (r= 0.86) even at 99% of confidence limit. The correlation is stronger particularly in the recent years.

Overall, the results of correlation between the monsoon trend and rice yield and the simulation both infer that the last decade of rice yield owes more to technological and management factors rather than monsoon onset. This might be due to various factors including improved seeds, and fertilizers. Quality seeds alone can contribute up to 15-20% yield (Basnet, 2012). As well, in the last ten years in Nepal, traditional rice varieties have been replaced by modern varieties (MOAC, 2011).

Conclusion

The monsoon occurrence events have not been following a definite trend and its characteristics such as onset, duration, distribution and withdrawal are quite unpredictable. Median monsoon onset date was found to be June 13 for the years 1968-2012. However, in recent years monsoon onset dates have been found to be shifting earlier.

An inverse relation was found between monsoon onset date and average rice yield (earlier the monsoon, higher the yield) in general and particularly before 2004. The correlation between yield and monsoon onset date is weaker in recent years.

Our findings suggest that to create more consistent and predictable rice yields integrated and holistic approaches are needed that include area-appropriate concepts, policy intervention, understandings of farmer constraints in achieving high yield, deployment of new technologies, promotion of integrated crop management, adequate supplies of inputs and farm credit, and strengthening of research and extension linkages (FAO, 1999). Therefore, future research should focus on what factors have contributed most strongly to reducing the correlation between monsoon onset date and rice yield in the later years. We need to move away from the conventional belief that monsoon onset is the prime determinant in rice yields.

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Foot Note

1. Asadh is the 3rd month of Nepalese calendar which comprises approximately the 2nd half of June and 1st half of July.

References

AFP, 2009, accessed at: http://www.wfp.org/content/late-monsoon-brings-fear-food-shortage-nepal, July 5, 2009

Anbumozhi, V., Yamaji, E., Tabuchi, T., 1998. Rice crop growth and yield as influenced by changes in ponding water depth, water regime and fustigation level. Agricultural Water Management 37 (1998) 241-253.

Arora, V. K., Gajri, P. R, Uppal, H. S., 2006, Puddling, irrigation, and transplanting-time effects on productivity of rice–wheat system on a sandy loam soil of Punjab, India, Soil & Tillage Research 85 (2006) 212–220. doi:10.1016/j.still.2005.01.015

Arora, V. K., 2006. Application of a rice growth and water balance model in an irrigated semi-arid subtropical environment, agricultural water management 83 (2006) 5 1 – 5 7. doi:10.1016/j.agwat.2005.09.004

Basnet, B. M.S., 2012, Rice: water, Food Security and Climate change in Nepal, Hydro Nepal Journal of Water, Energy and Environment, Kathmandu, Nepal.

Belder, P., Bouman, B.A.M., Cabangon, R, Guoan, Lu, Quilang, E. J. P., Yuanhua, Li, Spiertz, J. H. J., Tuong, T. P., 2004,Effect of water-saving irrigation on rice yield and water use in typical lowland conditions in Asia, Agricultural Water Management 65 (2004) 193–210, doi:10.1016/j.agwat.2003.09.002.

Bouman, B. A. M., Lampayan, R. M., Tuong, T. P., 2007. Water Management in Irrigated Rice Coping with Water Scarcity. IRRI, Philippines.

Bouman, B. A. M., Tuong, T. P., 2000. Field water management to save water and increase its productivity in irrigated lowland rice. Agricultural Water Management 1615 (2000) 1-20.

Choudhury, B. U., Bouman, B. A. M., Singh, A. K., 2007. Yield and water productivity of rice–wheat on raised beds at New Delhi, India. Field Crops Research 100 (2007) 229–239. doi:10.1016/j.fcr.2006.07.009

Climate frontlines, 2009, accessed at: http://www.climatefrontlines.org/en-GB/node/528, on 22 Sept, 2009.

Dahal, N. M., 2009, Emerging Trend of Change in Rainfall patterns and its impact on Traditional Farming Systems, www.climatefrontlines.org

Dawe, D, 2005, Increasing Water Productivity in Rice- Based Systems in Asia- Past Trends, Current Problems, and Future Prospects. Plat Prod. Sci. 8 (3): 221- 230 (2005).

DFID, 2009, accessed at: https://dfid.blog.gov.uk/2009/08/14/the-monsoon-arrives-but-too-late/,14 Aug, 2009.

Dunn, B.W., Gaydon, D.S., 2011. Rice growth, yield and water productivity responses to irrigation scheduling prior to the delayed application of continuous flooding in south-east Australia. Agricultural Water Management 98 (2011) 1799–1807. doi:10.1016/j.agwat.2011.07.004

Food and Agriculture Organization, 1999, Report of the expert consultation on bridging the rice yield gap in the Asia- Pacific region, FAO regional office for the Asia and Pacific Bangkok, Thailand, December, 1999. http://www.dhm.gov.np/uploads/climatic/535305507monsoon%20onset%20n%20withdrawal.pdf

Humphreys, E.,Meisner, C.,Gupta, R., Timsina J., Beeche, H. G., Lu, Tang Yong, Singh, Yadvinder, Gill, M. A., Masih I., Guo, Zheng Jia, and Thompson, J. A., 2005. Water Saving in Rice Wheat Systems. Plant Prod. Sci. 8(3):242-258.

IRRI, 2006. Bringing Hope, Improving Lives: Strategic Plan 2007-2015. Los Baños, Philippines. In: Meshing mechanization with SRI methods for rice cultivation in Nepal by Rajendra Uprety

Joshi, N. P., Maharjan, K. L., Piya, L., 2011, Effect of Climate Variables on Yield of Major Food-crops in Nepal: A Time-series Analysis, Journal of

Contemporary India Studies: Space and Society, Hiroshima University.

Karki, K. K., 2009. An unpublished M.Sc. dissertation on Productivity And Economic Viability Of Rice Under Different Planting Pattern and Age of Seedlings Through System Of Rice Intensification (Sri),Chitwan, Nepal.

Mahajan, G, Bharaj, T. S.,Timsina, J., 2009, Yield and water productivity of rice as affected by time of transplanting in Punjab, India, agricultural water management 9 6 (2009) 5 2 5 – 5 3 2, doi:10.1016/j.agwat.2008.09.027

MOAC, 2009, Statistical information on Nepalese Agriculture, Kathmandu: Ministry of Agriculture and Cooperatives/Agribusiness Promotion and Statistics Division. In: Tripathi et al, 2012, Adopting rice technologies to Climate change, Hydro Nepal Journal of Water, Energy and Environment, Kathmandu, Nepal.

MOAC/WFP, 2011, Crop Situation Update: A Joint Assessment of 2010 Summer Crops and Outlook for 2011 Winter Crops, Kathmandu: Ministry of Agriculture and Cooperatives and FAO World Food Program In: Mehata, R. K., Shah, S. C., 2012, Impact of Climate Change on Water Availability and Food Security of Nepal, Hydro Nepal Journal of Water, Energy and Environment, Kathmandu, Nepal.

MOAD, 2012, Statistical information on Nepalese Agriculture, Kathmandu: Ministry of Agriculture and Cooperatives, Agri-business Promotion and Statistics Division, Agri Statics Section, Singha Durbar, Kathmandu, Nepal.

Nepali times, 2009, accessed at: http://nepalitimes.com/news.php?id=16182#.UgEFf9LTzfI, on July 31, 2009

Pirmoradian, N., Sepaskhah, A. R., Maftoun, M., 2004. Effects of water saving Irrigation and Nitrogen Fertilization on Yield and Yield Components of Rice (Oryza Sativa L.). Plant Prod. Sci.7 (3) : 337 – 346 (2004).

Rijal, K. P., 2012. Yield response to water, using AquaCrop, a crop water productivity model, a case study of farm level rice cultivation in Chitwan district of Nepal. An unpublished thesis report for MSc in water resource engineering.

Sapkota, 2013 accessed at: http://sapkotac.blogspot.com/2013/06/monsoon-and-agriculture-production-in.html on11 June 2013

Schultz, Bart, C. D. Thatte and V. K. Labhsetwar, 2005. Irrigation and drainage. Main contributors to global food production. Irrigation and Drainage. 54.3.

Singh, K. B., Gajri, P. R., Arora, V. K., 2001. Modeling the effects of soil and water management practices on the water balance and performance of rice. Agricultural Water Management 49 (2001) 77-95.

Tabbal, D. F., Bouman, B. A. M, Bhuiyan, S. I., Sibayan, E. B., Sattar, M. A., 2002. On-farm strategies for reducing water input in irrigated rice; case studies in the Philippines. Agricultural Water Management 56 (2002) 93–112.

The Himalayan Times, 2012, accessed at http://www.thehimalayantimes.com/fullNews.php?headline=Late+monsoon%26sbquo%3B+fertiliser+crunch+to+hit+rice+production+&NewsID=340460, on 21 July, 2012.

The Kathmandu Post, 2012a, an accessed at: http://www.ekantipur.com/the-kathmandu-post/2012/08/06/money/un-food-agency-poor-monsoon-likely-to-hit-nepals-paddy-output/238110.html, on 7 August, 2012.

The Kathmandu Post, 2012b, accessed at : http://www.asianewsnet.net/news-40044.html, on 11 Dec, 2012.

The Kathmandu Post, 2013, accessed at : http://m.ekantipur.com/the-kathmandu-post/2013/06/10/money/ nepal-to-face-rice-deficit-of-900k-tonnes-this-year/249829.html, on June 10, 2013.

Tripathi, B. P., Mahato, R. K., Yadav, R. B., Sah, S. N., and Adhikari, B.B., 2012, Adopting rice technologies to Climate Change, Hydro Nepal Journal of Water, Energy and Environment, Kathmandu, Nepal.

Tuog, T. P., Bhuiyan, S. I., 1999. Increasing water-use efficiency in rice production: farm-level perspectives. Agricultural Water Management 40 (1999) 117±122.

Tuong, T. P., Bouman, B. A. M., 2003. Rice Production in water –Scarce Environments. In Kijne, J.W., Barker, R., Molden, D., (Eds.), Water Productivity in Agriculture: Limits and Opportunities for Improvements. CAB International.

WRS, 2002, Water Resource Strategy Nepal, His Majesty's Government of Nepal, Water and Energy Commission Secretariat, Singha Durbar, Kathmandu, Nepal.

Yang, Y., Wilson, L. T., Wang, J., 2012. Site-specific and regional on-farm rice water conservation analyzer (RiceWCA): Development and evaluation of the water balance model. Agricultural Water Management 115 (2012) 66– 82. http://dx.doi.org/10.1016/j.agwat.2012.08.010.

Zeng, L., Lesch, S. M., Grieve, C. M., 2003, Rice growth and yield respond to changes in water depth and salinity stress. Agricultural Water Management 59 (2003) 67–75.