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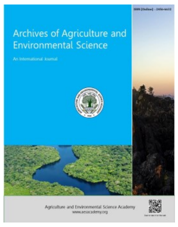

ORIGINAL RESEARCH ARTICLE

Importance of weather prediction for sustainable agriculture in Bihar, India

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ABSTRACT

The current study deals with the climate variability leads to economic and food security risks in Bihar state of India and rest of other part also due to its significant influences on agriculture. In the Bihar state, where agriculture is underachieve because of monsoon dependence and out of the 100 percent only 30 percent is fed by canal water. Climate is changing and its effects on agriculture are uncertain, and to get maximize output and to improving their livelihood within the major constraint, there is need for accurate weather forecast and information. Due to this the dependency of the agriculture sector on monsoon correlates accurate weather forecasts with high demand. The key factor in all agriculture policy is the weather forecasting information which involves enhancing farm risk management. The analysis showed that a 75% accuracy of agro-meteorological information is necessary for the agro-meteorological information to be worthwhile. However, challenges are there to the uncertainty of climate forecasts and to the complexities of agricultural systems. If better predictions of climate were available three to six months ahead of time, it may be possible to modify decisions to decrease unwanted impacts and to take advantage of expected favourable conditions. Also farmer is better geared to decide about his choice on crop management including appropriate time for sowing, wedding, and harvesting and fertiliser application.

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INTRODUCTION

India is primarily an agricultural country and its economy (despite the growth of the tertiary sectors) is still largely influenced by what comes from the farm. The Meteorological conditions of any region play a crucial role in determining success or failure of crop production during the phase of growth and development of plant. Variability in the weather (i.e. delay in the monsoon, excessive rains, low rainfall, flood, high temperature, etc.) during the crop period, would affect the crop growth and the quality and quantity of the total production. Weather forecast support to improve the production of agriculture in scientific way, reduce risks and losses, increase crop and water use efficiency (Cabrera *et al.,* 2007; Ziervogel and Opere, 2010; Hansen *et al.,* 2011). By optimum weather forecasts, losses in crop can be optimized by undertaking some crop management in time and make selection of agriculture crops best suitable to the anticipated climatic conditions (Kenkel and Norris, 1995). The real and probable climatic conditions and its influence on sowing, irrigation scheduling, and overall crop management is predicted by the weather forecasting which often helps to advice the farmers. Stone and Meinke (2006) looked at weather information as a product for farmers in two distinct forms; tactical (short-term) and strategical (long-term) based on the time range to which key management decisions are influenced by weather information. Therefore, understanding the expected short run and long run changes in the weather variables will go a long way to assist smallholder farmers plan for the framing activities with the aim of lessening the potential effect of the weather.

The Intergovernmental Panel on Climate Change (IPCC) has prognosticate that considering the spate of changes in climatic conditions, rain fed crop production could decrease by 50% by 2050 (IPCC, 2007). The effects of climate change on agriculture are uncertain but globally scientists agreed on the fact that it will make some farmer's environment worse off whilst improving the environment of others. Most promising and explored means to mitigate climate change is the adoption and use of technological innovations such as irrigation, mechanization, fertilizers, rainwater harvesting technologies, pesticides/insecticides, meteorological information and new crop varieties tolerant to adverse climatic conditions as solution for climate threat (Chuku and Okoye, 2009). Foremost the lacks of financial support to farmers and deficient institutional support have been thought of as the main reason of the low absorption of technological options as mitigation strategies for climate change.

Rollins and Shaykewich (2003) observes the benefits generated from weather information usage by commercial users. Williamson *et al.* (2002) explained how enhanced forecasts made by satellite data tends to several social and economic benefits. In addition, Davidson *et al.* (2012) suggested that the economic value of environmental prediction of weather information to selected enterprises involved in the production, transmission and distribution of energy. On the other hand, several studies have also looked at value of weather information with respect to agriculture. Predicatori *et al.* (2008) govern the real value of weather forecast information additionally to cost benefits analysis, Spicka and Hnilica (2013) gave overview on data sources and evaluation of weather derivatives.

Agriculture is the only single largest private sector occupation in Bihar and can be considered the insecure business. Hence, the goal of the agricultural production system should be to maximize income of land owning and landless rural populace to ameliorate their livelihoods. The vulnerability to income and consumption shocks makes it imperative to develop formal agricultural insurance mechanisms to cope with such risks. Thus the aim of the present study is to catalogue study conducted in Bihar relative to the use of agro-meteorological forecasts and to determine the desired information attributes, the most played strategies by farmers and the mean value added by the use of these information. This study built a meta-database and by using descriptive statistics it will provide the mean benefit derived from the use of climate forecast and the conditions under which these forecasts are useful or harmful.

MATERIALS AND METHODS

Study area: Bihar is located in the eastern region of India along with latitude 24°-20'-10" N ~ 27°-31'-15" N and longitude 82°-19'-50" E ~ 88°-17'-40" E. It is an entirely land–locked state, in a Sub Tropical region of the temperate zone. It is surrounded by Nepal in the north and by Jharkhand in the south. The river Ganga which flows through the middle from west to east divides Bihar plain is into two unequal halves. Thus the very geographical setting of the State coupled with hydrometeorology, hydrology, geomorphology and topography prevailing in the region makes it one of the worst flood affected region in the world. The entire North Bihar is crisscrossed by the major rivers such as: the Ghaghra, the Gandak, the Bagmati, the Kamla-Balan, the Kosi and the Mahananda which all, meet the mighty Ganga on its left bank.

The study area has a total geographical area of 93.60 lakh hectares over which it houses a population of 82.9 million, respectively generating a population density of 880 persons per sq. km (Census 2001). Gross own area in the State is 79.46 lakh hectares, while net sown area is 56.03 lakh hectares. Particularly in Bihar, there are around 1.04 crore land holdings out of which around 83 percent are marginal holdings of size less than 1 hectare (Table 1). With around 90 percent of the total population living in rural areas, agriculture as the primary feeder of rural economy continues to operate not only on margins of land but also on the margins of human enterprise, its potency being among the least in the country. Without increasing returns to these margins, not much can be done realistically to develop the agricultural sector. Thus, the role of agriculture keeps up to define both the capability and impulsion to development in Bihar. Since farmers have small land holdings, the agriculture income growth is highly essential to sustain. Strategic approach and meteorological forecast is needed to enhance the farm income and to create better on farm opportunities. Agriculture not only provides pollination support to crops and enhances the yield, but it provides additional income.

Methodology: The present work was based on Hilton (1981) work which describes the evaluation of agro-meteorological information. The Hilton (1981) supposes that the farmer knows the historical distribution of different climate conditions and uses this distribution in determining optimal inputs. As each model is different, only the general framework to value meteorological forecasts is presented. Before the meteorological forecasts are available, the farmer maximizes expected net returns given the historical distribution on the meteorological condition(s) of interest:

$$\pi(H) = \max_D E_C\{[w(D,c)]h(c)\} \quad (1)$$

where $\pi(H)$ is the maximum expected net returns using the historical meteorological distribution (without the meteorological forecasts), Ec represents the expectation operation taken over the meteorological condition(s) of interest, c, and $h(c)$ represents the historical meteorological condition(s) probability density functions (pdf), w is net return function, and D represents the decision set.

When the decision maker obtains forecast F_i that modifies the decision maker's knowledge concerning meteorological condition(s), the problem becomes:

$$\pi(F_i) = \max_D E_C\{[w(D,c)]g(c/F_i)\} \quad (2)$$

where $\pi(Fi)$ is the maximum expected net returns associated with forecast F_i and $g(c/Fi)$ is the modified (probability density functions) density function associated with the forecast. Forecast F_i is only one of many possible forecasts. Expected net returns from using the meteorological forecast information are:

$$\pi(F) = E_{F_i}\{\pi(F_i)f(F_i)\} \quad (3)$$

where $\pi(F)$ is the maximum expected net returns associated with forecast system F and $f(Fi)$ is the density function associated with receiving the different forecasts, i. The expected value of the meteorological forecasting system is:

$$V = \pi(F) - \pi(H) \quad (4)$$

The gain from information is the difference between the net returns when the information is used optimally and the expected net returns when the decisions are made optimally without the forecasts. Consistency is maintained with the probability density function associated with the forecasts, such that the system is forecasting climatic events and not altering the overall historical probability of a particular event.

RESULTS AND DISCUSSION

According to Murphy (1993), forecasts are considered "authentic" when the forecast probability is an exact estimation of the relative frequency of the predicted outcome. The use of meteorological forecasts depends highly on the degree of ease of access and the ease of use of the forecasts. For meteorological forecasts to be valuable it has to be delivered in advance and at the right time to enable farmers to make appropriate decisions. The delivery of information in advance and at the appropriate time is defined as timeliness. Sultan *et al.* (2009) think that this attribute can affect significantly the value of meteorological forecasts. The simulation model or ex-ante approach generally simplifies farmer's environment, assuming that farmers maximize utility or profit and finally varying the characteristics such as lead time, accuracy and details of the meteorological forecasts to derive the value of the meteorological forecasts (Sultan *et al.,* 2009).

The role of rainfall in Indian agricultural system is very important as in most of the states of the country the cultivation practices like preparation of the schedule of crops cultivation, agriculture field, sowing of crops, fertilization are rainfall dependent. In most of the regions the scarcity of irrigation water makes the farmers dependent on the weather prediction and weather forecast. Sometimes the lands remain uncultivable due to the failure of monsoon, thus accurate weather forecasting is very important of agriculture in Indian states (Cabrera *et al.,* 2007; IPCC, 2007) During the present study, it is clearly indicated from the values presented in the Table 1 that nearly 82.9 percent farmers are falls under the marginal category of land holding and do not having good sources of irrigation and they are dependent on the precipitation for growing their crops. Similarly the small, semi medium categories of the farmers in Bihar are dependent on the rainfall for the cultivation of their land as they do not have their own irrigation sources (Table 1). Therefore, forecasting of weather information is very helpful tool for the planning of agricultural crops in the Bihar state. The medium or large categories sometimes having their own sources of irrigation water and comparatively less dependent on the rainfall (Table 1). In the Bihar state, where agriculture is underachieve because of monsoon dependence and out of the 100 percent only 30 percent is fed by canal water. The past evidence show that forecasts predicting normal rainy season is merely useful for farmers and in most studies normal rainy season is used as control year (without knowledge regarding the coming rainy season). Sultan *et al.* (2009) foresaw in Senegal that farmer's income would increase significantly, by 13.8%, 8.5% and 15% for one, two and three month in advance forecasts of the rainy season, respectively when the dry season is correctly forecast. To get the optimal lead time author have chosen a game theory. The optimal lead time computed is 1-2 month before the onset of rains. The lead time is highly correlated with the accuracy moreover the value of climate forecasts was also highly correlated with the accuracy of the agro-meteorological information. The results of the present analysis showed that a 75 % accuracy of agro meteorological information is necessary for the meteorological information to be worthwhile. If the accuracy of information is less than 60% then the use of meteorological information will be harmful as discuss (Ziervogel *et al.,* 2005).

Table 1. Distribution of farmers along with land holding in Bihar, India.

Category of farmers	No. of holdings	Operational holding (in Ha.)
Marginal (0-1 Ha.)	85, 45,932 (82.9%)	27, 87, 789 (40.8%)
Small (1-2 Ha.)	10, 05,650 (9.6%)	13, 00,667 (19.0%)
Semi medium (2-4 Ha.)	5, 90,650 (5.7%)	15, 82,279 (23.1%)
Medium (4-10 Ha.)	1, 78,295 (1.7%)	9, 75,355 (14.3%)
Large (10- above Ha.)	11, 570 (0.1%)	1, 93,760 (2.8%)
Total	1, 04, 32,417 (100%)	68, 39,850 (100%)

Agro-meteorological support for farm management: Present section describes about the weather based farm advisories as a support system as shown in Figure 1. This system organised after the characterization of agro-climate, including length of crop growing period, moisture availability period, distribution of rainfall and evaporative demand of the regions, weather requirements of cultivars and weather sensitivity of farm input applications.

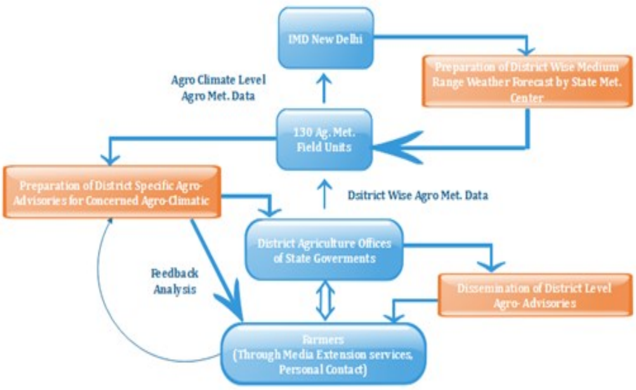

Figure 1. *Agro-meteorological advisory service system for farm management.*

Conclusions

The farmers obtain highest output and improve their livelihood within the main limitation as dependence on rain-fed agriculture, therefore having access to weather forecast information is very important. It is an urgent need of metrological report that is easily accessible and understandable to the farmers. The delivery of the weather information should be a key factor in all the agricultural policies and discussions in enhancing farm risk management. As complexities of agricultural systems and the uncertainties of climate forecasts recommended that a coordinated effort is needed if this technology is to be routinely used in agriculture in the future. In this regard there is a need to increase complementarily among information, technology and public intervention by; improved information on agro climatic potential i.e., a greater range of measurement, more computer–based analysis, more agro climatic screening of environments to match agricultural activities to regional weather–types and improve weather forecasting or by improved use of new agricultural technologies (such as high–yielding varieties) to increase production potential in good years and reduce losses in poor years; A focus on integrated regional development to reduce overall vulnerability to drought by increasing public awareness; and development of a consistently applied and widely known set of drought policies to reduce the uncertainty that stems from ad hoc public intervention.

This present study provide insight story of determinants to use of climate information related to perception and communication, and some evidence that improved presentation may overcome some of the barriers and enhance utility. The weather information should be given by the agro-meteorological stations before one or two month before the onset of the rainy season that can allow the farmers to change critical decisions such as crops sowing schedule, crop varieties, cropping ratio, intensification of production, allocation of labour and capital. The results of the analysis showed that a 75% accuracy of meteorological information is necessary for the meteorological information to be worthwhile. Moreover the weather information forecasted by the agro-meteorological can support to plan a smart fertilizer subsidy programme as well as smart improved seed programme. Moreover, the findings of this study have contributed interesting additional research hypotheses, and have influenced the development of several research larger proposals.

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