Forecasts of Agricultural Production

Ranjana Agrawal and Ramasubramanian V.

Indian Agricultural Statistics Research Institute
New Delhi

- Reliable and timely forecasts
  - Useful for proper, foresighted and informed planning
  - More so, in agriculture which is full of uncertainties such as weather, production, policies, prices, etc.
- Agriculture now-a-days has become highly input and cost intensive. Without judicious use of fertilizers and plant protection measures, agriculture no longer remains as profitable as before
- New pests and diseases emerging as added threat

- Under the changed scenario, forecasting various aspects relating agriculture becoming essential

- Pre-harvest forecasts of crop production
  - required for various policy decisions relating to storage, distribution, pricing, marketing, import-export, etc.

- For long term planning, projections of production are required

Pre-harvest forecast system for crop production

- Official advance estimates of rice, wheat, major crops under the categories of coarse cereals, pulses, oilseeds, cash crops, foodgrains, horticulture and plantation crops
- Issued by Directorate of Economics and Statistics
  - First estimate : September (Kharif crops)
  - Second estimate : January
    - September estimates of kharif revised
    - First advance estimate of rabi crops
  - Third estimate : March end / April beginning
    - Earlier estimates of kharif and rabi firmed up / validated.

- Fourth estimate : End of May
  - Most of the rabi crops harvested
  - Estimates of both kharif and rabi seasons and likely assessment of summer crops.

- Mainly guided by visual observations
  - Validated on the basis of inputs from SAC, proceedings of CWWG, water availability in major reservoirs, availability /supply of inputs etc.

- These advance estimates not objective
  - Need to develop statistically sound objective forecasts

Methodologies for pre-harvest forecast of crop production

- Production has two components
  - Area
  - Yield
- Area availability before harvest through Timely Reporting Scheme (TRS) and remotely sensed (RS) data

  => Methodology required for forecasting yield rate
- Different Approaches
  - based on weather parameters, agricultural inputs, plant condition measurements, farmers' appraisal, remotely sensed data

- Factors affecting crop yields
  - Weather
  - Technological changes
    - include variety, fertilizer, irrigation, management, pest and disease control measures
    - Technological factors increase yield smoothly through time

- Time parameter can be used to account for technological factors.

Crop - weather relationship

- Weather affects the crop differently during different stages of development
- distribution pattern of weather over the crop season is important
- necessity of dividing the crop season into finer intervals

  => large number of parameters will have to be evaluated from the data

  => long series of data required (not available in general)

Problem can be solved by

- taking weather variables of some periods only which show significant correlation with yield
- Use of weekly / fortnightly data, construction of suitable weather indices to be used in the model alongwith trend and / or agricultural inputs.

Fisher's method

- Suggested model requiring small number of parameters to be estimated while taking care of distribution pattern of weather over the crop season
- Used for studying influence of rainfall on wheat yield
- Divided crop season into 5 / 7 days interval
- Relation of crop with rainfall

$Y = A_0 + A_1X_1 + A_2X_2 + \ldots\ldots. + A_nX_n$

(here Y denoted yield and X_w rainfall in w-th week = 1,2,…,n)

Assumption : Effect of change in weather in successive periods follow some mathematical law

- Expressed weather and its effect on yield in successive periods in terms of orthogonal polynomials in time

$A_w = a_0[f_0(w)] + a_1[f_1(w)] + \ldots\ldots\ldots + a_k[f_k(w)]$

$X_w = \rho_0 [f_0(w)] + \rho_1 [f_1(w)] + \ldots\ldots\ldots + \rho_k [f_k(w)]$

Where ρ_I's are distribution constants.

Substituting in regression equation & using properties of orthogonal and normalised functions

$Y = A_0 + a_0 \rho_0 + a_1\rho_1 + \ldots\ldots\ldots a_k\rho_k$

- He suggested $k = 5$

=> no. of constants to be evaluated = 7

Hendricks & Scholl model

- Divided crop season into weekly intervals
- Suggested second degree polynomial in week number to express effects
- Taken weather variables as such
- Introduced additional variate T (year) to make allowance for time trend

$A_w = a_0 + a_1 w + a_2 w^2$

Substituting in regression equation

$$Y = A_0 + a_0 \sum_{w=1}^{n} X_w + a_1 \sum_{w=1}^{n} wX_w + a_2 \sum_{w=1}^{n} w^2 X_w + bT$$

- number of constants to be evaluated = 4
- extended the model to study joint effects

- Baier's classification of crop weather models
  - Crop growth simulation models
  - Crop weather analysis models
  - Empirical statistical models
- Most commonly used models in crop forecasting are Empirical Statistical models.
  - several variables are related to crop responses such as yield
  - regression analysis most commonly used
  - independent variables include weather variables, agrometeorological variables, soil characteristics or some suitably derived indices of these variables.

- Some commonly used indices are
  - Water Requirement Satisfaction Index
  - Thermal Interception Rate Index
  - Growing Degree Days
  - Southern Oscillation Index
- To account for the technological changes year or some function of time is used
  - Two time trends
- Use of moving averages of yield for technological changes

- Joint Agricultural Weather Information Centre employs crop weather analysis models

- USDA and FAO are the two organisations that systematically forecast world agricultural production and global crop information based on weather
  - Daily monitoring of satellite weather images and meteorological data
  - Daily, weekly and seasonal summaries are processed and merged with historical weather and crop data
- Development of index depending on water deficit / water surplus in successive periods of crop growth (FAO work)
  - useful for forecasting rainfed crops

Work In India

- Crop growth simulation models
  - Water Technology Centre (IARI)
  - ICRISAT
  - For selected crops at selected locations
  - Actual weather upto the time of forecast and normal, thereafter
- Limitations
  - Requirement of large and detailed data base

IMD models

- Based on time series data on weather
- Empirical statistical models using correlation regression techniques
- Identification of significant correlation coefficients between yield and meteorological parameters during successive overlapping periods of 7-60 days of crop growing season.

  - Critical periods identified analysing correlation coefficients for statistical and meteorological significance
  - Stepwise regression using these parameters in critical periods alongwith trend
- Forecasts for kharif rice
  - 26 meteorological sub-divisions (15 states) and country as a whole
    - August
    - Revised in September and October
    - Final forecast : November / December

- Forecast for wheat
  - 16 meteorological sub-divisions
  - January
  - Updated in subsequent months
  - Final forecast in March / April

- Performance, by and large satisfactory
  - Whenever large and persistent variation between forecast and actual, model updated and modified using predictors like Yield Moisture Index, Generalised Monsoon Index, Moisture Stress, Aridity Anomaly Index, etc.

IASRI approaches

- At IASRI, model by Hendricks and Scholl was modified by expressing effects of weather on yield in successive weeks as a quadratic function of respective correlation coefficients between yield and weather instead of week no. Under this assumption model becomes

$$Y = A_0 + a_0 \sum X_w + a_1 \sum_{w} r_w X_w + a_2 \sum_{w=1}^{n} r_w^2 X_w + bT + e$$

Forecast model

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{2} a_{ij} Z_{ij} + \sum_{i \neq i'=1}^{p}\sum_{j=0}^{2} a_{ii'j} Z_{ii'j} + bT + e$$

Where

$$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw}$$

$$Z_{ii'j} = \sum_{w=1}^{m} r_{ii'w}^{j} X_{iw} X_{i'w}$$

r_{iw} is correlation coefficient of yield adjusted for trend effect with i-th weather variable in w-th week/fortnight

$r_{ii'w}$ is correlation coefficient of adjusted yield with product of i-th and i'-th weather variables in w-th week/fortnight

m is week/fortnight of forecast

p is number of weather variables used

e is random error distributed as $N(0,\sigma^2)$.

- Model used for studies on rice crop in Raipur district
- Performed better than the model proposed by Hendricks and Scholl.
- Reliable forecasts when crop is 11 weeks old within 5 per cent deviation from actual
- Model stable for further 5 years.

Further modifications

- Correlation coefficients after adjusting yield for trend effect
- Effects as linear function of respective correlation coefficients
- Effects of quadratic terms of weather

=> In all, eight models using combinations of these modifications were studied for Rice crop in Puri district and wheat in Amritsar.

Findings

- Models using correlation coefficients based on yield adjusted for trend effect better
- Inclusion of quadratic terms of weather did not improve the model
- Second power of correlation coefficient did not improve the model

Modified model

$$Y = A_0 + \sum_{i=1}^{p} \sum_{j=0}^{1} a_{ij} Z_{ij} + \sum_{i \neq i'=1}^{p} \sum_{j=0}^{1} a_{ii'j} Z_{ii'j} + cT + e$$

where

$$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw} \quad \text{and} \quad Z_{ii'j} = \sum_{w=1}^{m} r_{ii'w}^{j} X_{iw} X_{i'w}$$

Forecasts of subsequent years

Rice - Raipur, forecast with 5% deviation from observed yield

Rice - Puri , forecast with 10% deviation from observed yield

Wheat - Amritsar, forecast with 10% deviation from observed yield

Sugarcane -Kolhapur, forecast with 5-10% deviation from observed yield

Effect of technology on yield

- Relationship of yield with year and agricultural inputs linear
- Contribution of agricultural inputs significant
- Additional contribution of agricultural inputs after including year into the model negligible

=> year can be used to depict impact of technological changes on yield

=> forecast model using year and weather indices

Limitation

- Requires long series data for 25-30 years for reliable forecasts which may not be available

Models for agro-climatic zone

- **Crops and areas covered :**

  Wheat – Vindhya Plateau Zone

  Rice – Chattisgarh Plain and Bastar Plateau zone taken together.
- **Data used :**

  District-wise time series data

Model

- District level model using composite weather indices modified by including agricultural inputs, previous year's yields and 2-5 years moving averages of yield to take care of variation between districts within the zone.

Conclusion

- Model using weather and agricultural inputs.
- Reliable forecast when crops are 12 weeks old.
- Reliable forecasts even if data on some districts are not available, either at the stage of developing model or at forecasting stage.
- Data requirement 10-15 Years.

Yield forecast at state level

- Crops covered
  - Rice, Wheat & Sugarcane
- Area: U.P.
- Models using weighted indices only.
- District-wise better than agro-climatic zone level models
- Reliable forecasts for rice and wheat when crop is 11 weeks old i.e. 2 months before harvest and for sugarcane in middle of September using data of 14 fortnights

Model based on discriminant function analysis

- Crop : Rice
- District : Raipur
- Variables used : Minimum Temperature
  Maximum Temperature
  Minimum Relative Humidity
  Maximum Relative Humidity
  Sunshine Hours
  Rainfall
  No. of Rainy days
  N, P, K

Methodology

- Based on yields adjusted for trend effect,years grouped in 3 categories :
  Congenial, Normal and Adverse.
- Linear / quadratic discriminant functions using weather data
- Weather scores for each year at different phases of crop growth.
- Regression model using weather scores, inputs and time trend as regressors.

- Appropriate model using quadratic discriminant function
- Time of forecast - Two months before harvest
- Limitations - Requirement of long series data

Models using water balance technique

- **Crops & Areas covered :**

  Sorghum - Delhi, Parbhani

  Maize - Delhi

  Rice - Raipur
- **Data used :**

  Pan-evaporation (Weekly)

  Rainfall (Weekly)

  Soil & crop characteristics

Methodology

- Deficit $= WR_i - AE_i$

  Where WR_i = Water requirement of the crop in i^{th} week.

  $= k_i \times evap_i$ where k_i is crop coefficient and $evap_i$ is pan evaporation in the i^{th} week.

  AE_i = Actual Evapotranspiration

Surplus if $S_i > WHC$

S_i = estimated soil moisture in the root Zone at the end of the i^{th} week.

$= S_{i-1} + R_i - WR_i$

R_i = rainfall in the i^{th} week

WHC = water holding capacity

- Stress due to deficit

  $St_i = deficit_i / WR_i$
- Stress due to surplus = 1
- Weighted stress index $= \sum_i W_i St_i$

  W_i is the weight for stress at the i^{th} week.
- Regression model using stress indices and time

◆**Time of forecast :**

Sorghum – 6 weeks before harvest
Maize – 4 weeks before harvest
Rice – 5 weeks before harvest

Forecast of subsequent years

- Sorghum Delhi
  % deviation – 1% to 11%
- Sorghum Parbhani
  % deviation – 3.5% to 10%
- Maize Delhi
  % deviation – 4.8%
- Rice Raipur
  % deviation – 1.1%

Models based on plant characters

- Plant characters can be taken as integrated effects of various factors affecting yield.
- May be clubbed with crop cutting surveys to obtain data on plant characters for advance estimates

USDA

$Y_i = (F_i \times C_i \times W_i) - L_i$

F_i : No. of fruits forecast to be harvested in i-th plot

C_i : Conversion factor to inflate plot count to per acre

W_i : Av. fruit wt. harvested / forecast to be harvested

L_i : Harvest loss

- Cannot be followed in India / tropical countries
  - time period from head emergence to maturity hardly one to two months (America 2-3 months)
- In India yield directly regressed on plant characters

Work done at IASRI

Crops and areas covered

Wheat	Ludhiana (Punjab)
	Aligarh (U.P.)
Paddy	Sambalpur (Orissa)
	West Godavari (A.P.)
	Ludhiana (Punjab)

Jowar	Sangli (Maharashtra)
Cotton	Baroda (Gujarat)
	Jalgaon (Maharashtra)
	Aligarh (U.P.)
Jute	24 Parganas (W.B.)
	Purnea (Bihar)
	Nadia (W.B.)

Tobacco	Prakasam (A.P.)
Sugarcane	Meerut (U.P.) Kohlapur (Maharashtra)
Groundnut	Rajkot (Gujarat)
Apple	Simla (H.P.)

Plant characters considered

Paddy / Wheat	Plant population, Plant height, No. of tillers, Length of earhead, Basal girth, No. of green leaves
Jowar	Plant population, Plant height, Length of earhead, No. of green leaves, Length and breadth of leaves
Cotton	Plant population, Plant height, Girth of internode, Spread of plant, No. of bolls/ plant
Jute	Plant population, Plant height, Girth of internode

Tobacco	Plant population, Height, Internode Girth, No. of curable leaves, No. of green leaves, Length and breadth of leaves
Sugarcane	No. of millable canes, Cane height, Girth, Length of third leaf and its maximum width
Groundnut	Plant population, No. of branches, Length of main axis, No. of flowers, pegs and pods
Apple	Height, Age, Girth, Canopy spread, Intensity of flowering, No. of apple drops

Sampling Design

- Stratified multistage random sampling design
- Tehsils /Talukas – Strata
- Villages – First stage unit
- Fields / Orchards – Second stage unit
- Plots / Trees – Third stage unit

Sample size : About 200 fields

Plot Size :

- Wheat, Paddy - 1 sq.m.
- Jute – 2 m.sq.
- Crops sown in rows – 3 to 5 rows of 3-5 mts. length
- Apple – Two trees

Recording of Observations

- Plant population and total tillers – counted on whole plot basis
- Other characters – Sub-sample of 5 plants

Periodicity

Wheat Cotton Jute	4 weeks interval starting from 4th week after sowing
Paddy	Monthly interval starting from one month after sowing
Jowar	15 days interval starting from 45 days after sowing
Sugarcane	Monthly interval starting from third month after planting
Apple	• Height, age, girth, canopy spread after flowering • Intensity of flowering and flowering condition at weekly interval during blooming • No. of apple drops after two months from blooming at 15 days interval.

Model

Between year model

- Model developed using past data and utilised to forecast current year
- Assumption : Present year is a part of composite population of previous years

Regression Approach

Taking data of one point of time

$$Y = a + \Sigma\, b_i X_i + e$$

Y = yield rate

X_i = plant character

e = random error

- Variables as such / transformed

Square root

Log

Inverse

Plant characters entering the model and time of forecast

Crop	Biometrical characters	R^2	Time
Paddy	Plant popn. & No. of tillers	0.50	2 months before harvest
Wheat	Plant popn. & No. of tillers	0.5-0.6	- do -
Jowar	Population, height, breadth of flag leaf and length of earhead	0.60	1 month before harvest
Cotton	Plant density, No. of bolls and first picking yield	0.80	2 months before harvest
Jute	Plant density, height and diameter	0.50	- do -

Crop	Biometrical characters	R^2	Time
Tobacco	Plant density, No. of curable leaves and height	0.4-0.7 Black soil 0.5 Red soil	12 weeks old
Sugarcane	No. of millable canes and height	0.70	3-4 months before harvest
Groundnut	Plant popn., length of main axis, No. of pegs and pods	0.50	1 months before harvest
Apple	Age, Girth, Intensity of flowering, No. of apple drops	0.4-0.6	3-4 months before harvest

Curvilinear model – graphic approach

- Hybrid Jowar – Sangli district
- Use of successive graphic approximations
- Forecast one month before harvest
- Standard error – 5%

Models using data of two or more periods

Model based on growth indices

$Y = b_0 + \Sigma\, b_i G_i + e$

Where $G_i = \sum_{w=n_1}^{n_2} r_{iw} X_{iw}$ is the index of the i-th character, w is the period identification, n_1, n_2 are the initial and final periods considered in developing the index of the character, r_{iw} is simple / partial correlation coefficient between yield and i-th character in w-th period.

- Model used for hybrid jowar in Sangli district (Maharasthra)

Conclusion

- Model using growth indices better than conventional linear regression model.
- Use of partial correlation coefficient better than simple correlation coefficient.

Time of forecast : One month before harvest

- Coefficient of determination increased from 0.60 (based on simple regression model) to 0.70

Standard error of forecast – 12%

Model using principal components of plant characters

- Model used for hybrid Jowar in Sangli district
- Time of forecast – one month before harvest
- Percentage deviation from observed yield – 12%

Limitations / Drawbacks of regression model

Least square technique used for fitting regression model

- Optimality properties of these estimates described in ideal setting, not often realised in practice
- Errors non normal
- Outliers and extremes
- Multi-collinearity
- Variables not in a proper form
- Regression based on different subsets of data sometimes produce different results.

Probability model based on Markov Chain

- Overcomes some of the drawbacks of regression models
- Model free; does not require any assumption about independent / dependent variables.
- Non-parametric interval estimates
- Robust against outliers and extreme values

Methodology

- Growth process of crop divided into phenological phases – stages
- At each stage, classes are formed on the basis of percentiles separately for each plant character
  - combination of these classes will give rise to states
- Transition probabilities are worked out which give transition probabilities of a plant or a group of plants moving from any possible state of one stage to any possible state of next stage
- These probability matrices are used to forecast yield distribution

Model used for **sugarcane in Meerut** district (U.P.)

- Time of forecast – 3 months before harvest
- Deviation from observed yield – 2-4%
- Finer states improve the model
- Requires a large data base
- Models using higher order Markov chains
- Models using higher order Markov chains through principal components and growth indices of plant characters
- Simulation based higher order Markov chain models
- Principal components based third order Markov chain models best

Within year growth model

- Expected to be better than between year model in abnormal year
- Useful for areas where past data are not available
- Model used for **rice & wheat** data at **IARI** research farm
- Modeling of growth pattern of crop yield components (like dry matter) using partial crop season data
  - Forecast of dry matter at maturity using this model

Logistic model

$$Y_i = \frac{\alpha}{1+\beta\rho^{t_i}} + e_i$$

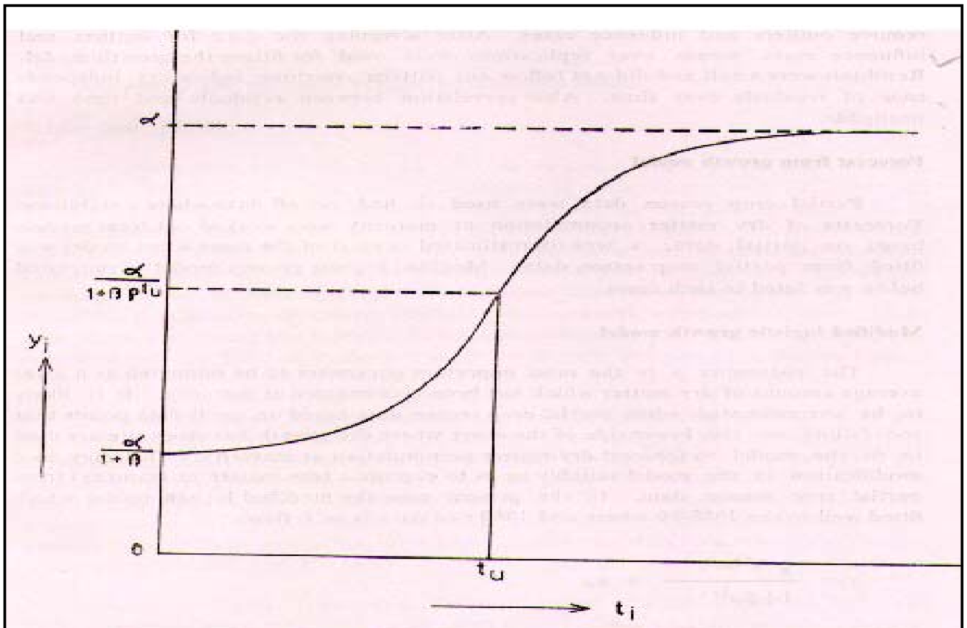
α, β and ρ are non-negative parameters and $0 < \rho < 1$

e_i = error terms, independent and distributed as $N(0,\sigma^2)$

t_i = independent time variable

Y_i = dependent growth variable

α = value of growth variable



-- LOGISTIC GROWTH MODEL

Limitation

α is over-estimated when partial crop season data falling on the lower side of the curve where growth has steep rise are used to fit the model.

Modified logistic crop growth model

$$Y_i = \frac{\alpha^{\sqrt{t_m / t_f}}}{1 + \beta\rho^{t_i}} + e_i$$

T_m is the time of maturity and t_f is the time of forecast

- Time of forecast – one month before harvest
- Percent deviation from observed - 5%

Use of farmers' appraisal

- Data collection from farmers' fields
  - Cost and labour intensive
  - Cannot be used on operational basis unless collection of such data is combined with crop cutting surveys
- Models using Farmers' appraisal
  - Farmer best judge of likely production
  - Farmers' appraisal data can replace some of the plant characters requiring expertise / use of sophisticated instruments

    => cost reduction of data collection
  - Sugarcane - Meerut
  - Model through regression and Markov chain approach
  - Farmers' appraisal has replaced plant height
  - Forecast - 3 months before harvest

Model using Bayesian approach

- Alternative approach of forecasting based on farmer's expertise
- Involves collection of expert opinion from farmers in a number of rounds regarding their assessment of likely crop yield for development of yield distribution, prior probabilities, likelihoods and finally application of Bayes' theorem for obtaining Bayesian forecast.
- Study for Wheat crop – Muzaffarnagar district
- Forecast - 2 months before harvest

- Quick and less expensive
- Provides forecasts representing composite thinking of farmers engaged in cultivation
- Accuracy expected to be more than purely eye estimates based forecast

Use of double sampling

- Data collection from larger sample for parameters not involving much cost and / or sophisticated instruments
- Data collection from sub-sample for parameters cost intensive and / or require sophisticated instruments
  - Prediction of remaining units using relationships of these parameters with parameters collected on larger sample

- Forecast model using data on all parameters collected / predicted
- Sugarcane – Meerut
- Forecast with same reliability at reduced cost on data collection

- **Use of remotely sensed data**
  - Forecasting Crop Acreage and Production Estimation Project (CAPE) since 1988 for forecasting acreage and production of major cereals, oilseeds and fiber crops.
  - Funded by Ministry of Agriculture
  - Being executed jointly by SAC, State Remote Sensing Centres, State Departments of Agriculture and Agricultural Universities.

Models developed at SAC

- Acreage forecasts using remote sensing data
- Productivity using meteorological / agrometeorological models

- Wheat – Major wheat growing states and at All India level
  - Apriori forecasts – December – ARIMA models
  - In-season multiple forecasts
  - Acreage – Multi-date IRS Wide Field Sensor data
  - Productivity - Relationship of de-trended yields with weather parameters at meteorological sub-divisions
  - Forecasts integrated with crop area to state level

- Rice – National level forecast
  - Acreage - Multi date Synthetic Aperture Radar (SAR) data
  - Yield forecasts – trend / time series / rainfall based agrometeorological models
  - Forecasts – October and following January
- Detailed study in Orissa for kharif rice
  - four in-season forecasts
  - first at beginning of kharif rice crop using agro-meteorological models

- second district level acreage at mid growth season using two-dates, SAR data, yield using meteorological models

- third forecast late growth season district level acreage using three-date SAR data, yield using meteorological models

- fourth revised forecast incorporating field observations at maturity

Model at IASRI

- First order markov chain used for forecasting wheat yield
  - using data of IARI research farm on spectral parameters
  - reliable forecasts standard error less than 5% after two or three months after sowing

Integrated model

- Hybrid Jowar using plant characters and agricultural inputs
  - Regression model using growth indices
  - R^2 increased from 0.70 (based on plant characters only) to 0.78
- Apple using plant characters, crops inputs (N, P, K and FYM) and weather (Relative humidity, minimum temperature, maximum temperature and sunshine hours)
  - R^2 in the range 0.5 - 0.8 in contrast to 0.4 - 0.6 in models using plant characters alone
  - Reliable forecasts at blooming or fruit size development stage (3-4 months before harvest)
  - Error of forecast : 1.25 – 2.5%

- While evaluating forecasts from CAPE, need for national scale, multiple, in-season forecasts was felt

  - led to examining relative strength and weakness of each system of forecasting

- Formulation of integrated approach “Forecasting Agricultural Output using Space,Agrometeorology and Land-based observations” (FASAL)

Composite forecast

- Use of different types of variables not always possible for integrated model
- Alternative - composite forecast
  - forecasts obtained through various approaches and suitably combined
- Sugarcane in Kohlapur (Maharashtra)
- Strategies developed for combining forecasts from different models
  - S1 - Equal weights
  - S2 - Weights depending on variances of errors
  - S3 - Weights based on variances and co-variances of errors

- Selection of strategy depends on correlation coefficient (r) and variance ratio (VR) of errors of individual forecasts

For combination of two forecasts

S1 : $r \leq 0.70$ & $VR \leq 1.5$ or $r \leq 0.95$ & $VR \leq 1.2$

S2 : $r \leq 0.5$ & $2 \leq VR \leq 3$ or $r = 0$ & $VR \geq 2$

S3 : $r = 0.5$ & $4 \leq VR \leq 5$ or $r = 0.6$ & $3 \leq VR \leq 5$

National Crop Forecasting Centre

- Set up in November 1999 for proper coordination and assimilation of various methodologies and periodic crop forecasting of major crops
- Works as secretariat for Crop Weather Watch Group
  - Effective forum for regular multi-disciplinary interaction
- Weekly meetings of the group
- Useful for early warning system
- To play vital role in FASAL project

Projections of crop production

- Long-range forecasts
- Based on a multi-year forecasting scenario
- By projecting vision of past trends into the future in terms of tangible and intangible causes
- Assuming stability, continuity and predictable changes
- They aid in policy formulations for agricultural planning

Official Projections

- made by Working Group on Crop Husbandry, Demand and Supply Projections and Agricultural Inputs

  (Planning Commission)
- for X Five Year Plan (2001-02 to 2006-07) supply projections obtained on the basis of time series data using three methods
  - Method I : simple linear regression of production Y with time T
  - Method II : log-linear regression of exponential growth function $Y = a\, b^{T}$
  - Method III : multiple linear regression of production Y upon the explanatory variables

    - area under foodgrain production (A)

    - percentage of irrigated area (I)

    - fertilizer consumption (F)

Official Projections…

Projections using Method III are made assuming

- area under foodgrain production to remain around 124 million hectares
- proportion of irrigated area to go up from 40% to 45% same as in 1990's
- fertilizer consumption to grow at same rate as in 1990's

Projections for the year 2006-07 (terminal year of X-FYP)

Method I	:	224.8 million tonnes
Method II	:	228.2 million tonnes
Method III	:	243.1 million tonnes

The present trend suggests that these projections are unattainable/ highly overestimated

Supply projections of foodgrains for X-FYP
(in million tonnes)

Year	Actual	Method I	Method II	Method III
2002-03	174.77	211.8	212.9	223.0
2003-04	213.46	215.1	216.6	227.9
2004-05	204.62	218.3	220.4	232.9
2005-06	-	221.6	224.3	238.0
2006-07	-	224.8	228.2	243.1

Mid-term appraisal of X-FYP by Planning Commission

- Drought caused foodgrains output to fall to 174.2 m.t. in 2002-03
- foodgrain production subsequently recovered to 213.46 m.t. in 2003-04
- 204.62 m.t. in 2004-05 (Advance estimates as on 06.07.05)
- did not cross the 2001-02 level of 212.65 m.t. (except 2003-04 which was marginally more than 2001-02 level)
- The models used seem to be too simple to accommodate the actually existing dynamic and complex behaviour of the components of the agricultural system
- Actual performance well below the projections

Projection studies at research level

- Narain *et al.* (1985) - foodgrains production projections for 1990 under two alternative scenarios

  (i) constant trend of input factors used for the utilized period

  (ii) 10% increased level of input factors in 1990

  - Crop-wise production projections and summing over crops to get the total foodgrain production projections
  - By first projecting the independent variables themselves on the basis of their growth rates (by employing linear annual growth rates) and then substituting them in the production functions
  - Projected the foodgrain production for the year 1990 as 179.2 and 189.2 m.t. under the two alternative scenarios considered whereas the actual output of 171.04 m.t. in 1990
- Method III of the Planning Commission is similar to Narain *et al.* (1985).

Projection studies…

- Kumar (1997, 1998) have given supply projections of rice, wheat, coarse grains (sorghum, pearl millet, and maize), pulses and hence foodgrains (the total of these four commodities) under two different scenarios
  - constant growth in TFP (Total Factor Productivity i.e. the growth in the amount of output generated by a unit of input) as observed during 1971-88 (Scenario 1)
  - declining at the growth rate in TFP as observed between the periods 1971-80 and 1981-89 (Scenario 2)
  - concluded that if TFP growth is maintained at historical levels then our country may turn out to be net importer of foodgrains and emphasized on concerted efforts needed for strengthening agricultural development.

Projections (Kumar, 1997)

Year	Actual	Scenario I	Scenario II
1995	191.50	187.7	186.9
2000	209.80	217.6	212.5
2005	204.62	242.7	231.4
2010	-	271.3	252.1
2020	-	339.8	300.2

Projection studies (Kumar & Mittal, 2003)

- Provided the supply projections for foodgrains under four different scenarios
- The first scenario has been considered on certain baseline assumptions for
  - factor and product prices (charges/prices of Human labour, Animal labour, Machine labour, Fertilizer, rice, wheat)
  - infrastructure variables (% Net sown irrigated area, % villages electrified, % rural literacy)
  - supply factors (Rice TFP, wheat TFP), organic manure and Areas under rice and wheat
- It is assumed that the factor product prices would grow at the rate observed during 1971-97, the growth in the infrastructure variables, TFP and rice area will decelerate at the rate observed from 1971-85 to 1985-97 and zero growth is assumed for farm yard manure

Projection studies (Kumar & Mittal, 2003)…

- Medium and long-range prospects of major cereal supply were explored upto 2020 under the following scenarios
  - Scenario 1: Baseline assumptions
  - Scenario 2: Baseline assumptions without TFP growth
  - Scenario 3: Baseline assumptions without area growth
  - Scenario 4: Baseline assumptions without TFP and area growth
- Kumar and Mittal (2003) opined that as the possibility of area expansion is minimal and any increase in foodgrain production will be yield-based, the scenarios 3 and 4 appear to be more realistic
- projected foodgrains to be about 248-259 m.t. in 2020

Projections (Kumar & Mittal, 2003)

Year	Actual	Scen-1	Scen-2	Scen-3	Scen-4
2005	204.62	231.5	227.3	221.8	217.7
2010	-	250.7	243.8	234.3	227.6
2015	-	269.7	260.3	246.5	238.1
2020	-	289.2	277.2	258.8	248.3

Projection studies…

- Bhalla *et al.* (1999) estimated India's foodgrain production for 2020 to be 347 m.t., on the basis of annual compound growth rates considering eight different scenarios and extrapolations of past growth trends
- Ravichandran and Prajneshu(2002) have employed two dynamical modeling approaches viz. Bayesian Analysis of Time Series (BATS) and Structural Time Series Modelling (STSM) upon 1966-67 to 1998-99 data and forecasted India's foodgrain production in 2020 to be 281.5 m.t. and 285.2 m.t. respectively
  - These models were dynamical in the sense that they allow for changes in the parameter estimates as time passes
  - However, these time series models do not consider the factors that affect the response variable.

Projection studies…

Most projection approaches utilize growth rates

- Simple growth rate is given by

$$\frac{(\text{Current year estimate}) - (\text{Base year estimate})}{(\text{Base year estimate})} \text{ x } 100$$

- Compound growth rate r is calculated as

$$\left(\frac{\text{Current year estimate}}{\text{Base year estimate}} \right)^{1/t} \text{ x } 100$$

Projection studies…

- Compound growth rate is often calculated by assuming multiplicative error in the non-linear exponential functional form of the model $Y_t = y_o (1+r)^t$ (Y_t is response variable, y_0 is y at time t=0) and linearising the same by log transformation to apply OLS to this linear model

However, this procedure has many pitfalls

- Firstly, as time tends to infinity, the response variable under study becomes infinite which is unrealistic
- Secondly, the assumption of multiplicative error is quite often invalid
- Also, standard error of parameter estimates can not be found

Projection studies…

- Chandran and Prajneshu(2004) advocate non-parametric regression methodology for computation of growth rates which does not require any specification of functional form of the model and is free from stringent assumptions
- Prajneshu and Chandran (2005) has suggested that compound growth rates should be computed by using growth models such as monomolecular, logistic and Gompertz which describe satisfactorily the pattern followed by response variable over time
  - It is to be noted here that the growth rates herein also depend upon time apart from other parameter estimates.

Foodgrain Projections using recent data

- Eight different models - four linear and four non-linear models were utilised
- Upon 1988-89 to 2002-03 data (15 years)

Method I :

Simple linear regression of production Y with time T

Method II :

Log-linear regression of exponential growth function $Y=ab^T$

Method III :

Multiple linear regression of production Y upon the explanatory variables

- area under foodgrain production (A)
- percentage of irrigated area (I)
- fertilizer consumption (F)

Foodgrain Projections…

(for Method III, projections were based on the assumptions that

- area under foodgrains will remain around 124 million hectares

- fertilizer consumption and proportion of irrigation area will go up at the same rate (compound growth rate r calculated by taking log-linear transformation to the exponential model) as in last ten years period 1993-94 to 2002-03)

Upon 1978-79 to 2002-03 data (25 years)

Method IV :

Fitted model is ARIMA (1,1,0)

Foodgrain Projections…

- Upon 1978-79 to 2002-03 data (25 years)

  Four non-linear growth models (Methods V – VIII)

- Exponential $Y_t = y_0 (1+r)^t$
- Monomolecular $Y_t = K - (K-y_0) \exp(- r t)$
- Logistic $Y_t = K / [1+(K/y_0-1)\exp(- r t)]$
- Gompertz $Y_t = K \exp[\log_e(y_0/K)\exp(- r t)]$

  (here K is the carrying capacity of the system, Y_t is response variable, y_0 is y at time t=0, r is growth rate)

Foodgrain Projections…

Year	Actual	Method I	Method II	Method III	Method IV
2003-04	213.46	205.97	198.34	212.28	207.22
2004-05	204.62	208.29	200.34	216.40	188.93
2009-10	-	219.89	210.61	237.01	214.22
2019-20	-	243.09	232.76	278.24	241.97

Foodgrain Projections…

Year	Actual	Method V	Method VI	Method VII	Method VIII
2003-04	213.46	210.38	207.72	205.52	202.54
2004-05	204.62	214.59	209.79	207.11	204.42
2009-10	-	236.92	219.02	213.46	212.52
2019-20	-	288.81	232.76	220.52	223.43

Conclusions

- Demand/supply/production/gaps projections done by various approaches using
  - different assumptions
  - different inputs
  - different growth rates
  - different methodologies etc.
- Hence different projection figures are obtained for the same commodity using different approaches
- Need for adopting a holistic view taking into account impact of all factors in all dimensions and their interrelationships
- Agricultural systems are a complex phenomena with large number of parameters viz. seed, fertilizer, pesticide, management practices, weather etc.
- Need for blending economic and statistical methodologies for studying and projecting agricultural production

References

Agricultural Statistics at a Glance (2005). Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India.

Agrawal, Ranjana; Jain, R.C., Jha, M.P. and Singh, D. (1980). Forecasting of rice yield using climatic variables. Ind.J.Agril. Sci. 50(9) : 680-84.

Agrawal, Ranjana; Jain, R.C. and Jha, M.P. (1983). Joint effects of weather variables on rice yield, Mausam, 34 (2) :189-94.

Agrawal, Ranjana; Jain, R.C. and Jha, M.P.(1986). Models for studying rice crop-weather relationship, Mausam, 37(1): 67-70.

Agrawal, Ranjana and Jain, R.C. (1996). Forecast of sugarcane yield using eye estimate alongwith plant characters. Biometrical Journal, 38 (5) : 731-39.

Agrawal, Ranjana; Jain, R.C. and Mehta, S.C. (2001). Yield forecast based on weather variables and agricultural inputs on agroclimatic zone basis. Ind. J. Agril. Sci., 71(7) : 487-90.

Baier, W. (1977). Crop weather models and their use in yield assessments. Tech. note no. 151, WMO, Geneva, 48 pp.

Bhalla, G.S., Hazell, P. and Kerr, J. (1999). Prospects for India's Cereal supply and demand in 2020, Discussion paper 29, International Food and Policy Research Institute, U.S.A.

Chandrahas and Narain, Prem (1992). Pre-harvest forecasting of yield of apple. (IASRI Publication).

Chandrahas and Rai, T. (2001). Pilot study for developing Bayesian probability forecast model based on farmers' appraisal data on wheat crop. (IASRI publication).

Chandran, K.P. and Prajneshu(2004). Computation of growth rates in agriculture: Nonparametric regression approach, J. Ind. Soc. of Agril. Stat., 57 (Special Issue) : 382-92.

Fisher, R.A. (1924). The influence of rainfall on the yield of wheat at Rothamsted. Roy. Soc. (London), Phil. Trans. Ser.B.,213 : 89-142.

Frere, M. and Popov, G.F., (1979). Agrometeorological crop monitoring and forecasting. FAO plant production and protection paper, plant production and protection division, FAO, Rome.

Hendricks, W.A. and Scholl, J.C. (1943). Technique in measuring joint relationship. The joint effects of temperature and precipitation on crop yield. N. Carolina Agric. Exp. Stat. Tech. Bull. 74.

House, C.C. (1977). A within year growth model approach to forecasting corn yields. Economics, Statistics and Co-operative Service U.S. Department of Agriculture, Washing-ton, D.C.20250.

Jain,R.C., Agrawal, Ranjana and Jha, M.P. (1980) : Effects of climatic variables on rice yield and its forecast, Mausam 31(4) : 591-96.

Jain,R.C. and Agrawal, Ranjana (1992(a)). Probability model for crop yield forecasting. Biometrical Journal, 34(4) : 501-11.

Jain, R.C., Agrawal, Ranjana and Singh, K.N. (1992(b)). A within year growth model for crop yield forecasting. Biometrical Journal, 34(7) : 789-99.

Jain, R.C., Sridharan, H. and Agrawal, Ranjana (1984). Principal component technique for forecasting of sorghum yield, Ind. J. Agril. Sci. 54(6) : 467-70.

Jain, R.C., Jha, M.P. and Agrawal, Ranjana (1985). Use of growth indices in yield forecast. Biometrical Journal, 27(4) : 435-39.

Jain, R.C. and Ramasubramanian, V. (1998), Forecasting of crop yields using second order Markov Chains. Jour. Ind. Soc. of Agril. Stat. 51(1) : 61-72.

Jha, M.P., Jain, R.C. and Singh,D. (1981). Pre-harvest forecasting of sugarcane yield. Ind. J. Agril. Sci. 51(11) : 757-61.

Kumar, P. (1997). Food security: supply and demand perspectives, Indian Farming, December issue, 47 (9) : 4-9.

Kumar, P. (1998). Food Demand and Supply projections for India, Agricultural Economics Policy Paper 98-01, New Delhi: Indian Agricultural Research Institute.

Kumar, P. and Mittal, S. (2003). Productivity and supply of foodgrains in India, In “Towards a Food secured India: Issues and Policies”. Ed. S.Mahendra Dev, K.P.Kannan and Meera Ramachandran, Institute for Human Development and Centre for Economics and Social Studies, Manohar Publishers, 33-58.

Larsen, Grog. A. (1978). Forecasting Kansas wheat growth. Economics, Statistics and Cooperative Servi ce, U.S. Department of Agriculture. Washington D.C. 20250.

Matis, J.H., Gaito, T., Grant, W.E., Iwing, W.C. and Ritchie, J.T. (1985). A Markov chain approach to crop yield forecasting. Agril. Systems, 18 : 171- 87.

Matis, J.H., Birkett, T. and Boudreaux, D. (1989). An application of Markov chain approach to forecasting cotton yield from surveys. Agril. Systems, 29 : 357-70.

Mehta, S.C., Agrawal, Ranjana; Singh V.P.N. (2000): Strategies for composite forecast. Jour. Ind. Soc. of Agril. Stat., 53(3) : 362-72.

Narain, P., Pandey, R.K. and Sarup, S. (1985). On Foodgrains production projections, Agril. situation in India, 40 : 383-88.

Nealon, J. (1976). The development of within-year forecasting models for winter wheat. Research and development branch, Research Division, Statistical Reporting Service, U.S. Department of Agriculture.

Patel, N.K., Chakraborty, M., Dutta, S., Patnaik, S., Parihar, J.S., Moharana, S.C., Das, A., Sarangi, B.K. and Behera, G. (2004). Multiple forecasts of kharif rice in Orissa state - Four year experience of Fasal pilot study. Journal of the Indian Society of Remote Sensing, 32(2) : 125-44.

Prajneshu and Chandran, K.P. (2005). Computation of compound growth rates in agriculture : revisited, Agricultural Economic Research Review, 18 (to appear)

Rai, T. and Chandrahas (2000). Use of discriminant function of weather parameters for developing forecast model for rice crop. (IASRI Publication).

Ramakrishna, Y.S., Singh, H.P. and Rao, G. Nageswara (2003). Weather based indices for forecasting foodgrain production in India. Jounral of Agrometeorology 5(1) : 1–11.

Ramasubramanian, V. and Jain, R.C. (1999). Use of growth indices in Markov Chain models for crop yield forecasting. Biometrical Journal, 41(1) : 99-109.

Ramasubramanian, V., Agrawal, Ranjana and Bhar, L. (2004). Forecasting sugarcane yield using multiple Markov chains. (IASRI Publication).

Ravichandran, S. and Prajneshu(2002). Dynamical modeling and forecasting of India's foodgrain production, Proceedings of National Academy of Science, India, 72, B(1) : 37-46.

Sardana, M.G., Khosla, R.K., Ohri, N.K., Mitra, P.C. (1972). Pre-harvest forecasting of yield rate of jute. Jute Bull. 35 (7 and 8).

Sarkar, J. (2002). Forecasting rice and wheat yield over different meteorological sub–divisions of India using statistical models. In Symposium on "Crop Weather models in agriculture" at 56th Annual Conference of Indian Society of Agricultural Statistics held at Dharwad.

Saksena, Asha; Jain, R.C., Yadav, R.L. (2001). Development of early warning and yield assessment model for rainfed crops based on agrometeorological indices. Project report, IASRI, New Delhi.

Singh, B.H. and Bapat, S.R. (1988). Pre-harvest forecast models for prediction of sugarcane yield. Ind. J. Agril. Sci. 58(6) : 465-69.

Singh, D., Singh, H.P., and Singh, P. (1976). Pre-harvest forecasting of wheat yield. Ind. J. Agril. Sci. 46(10) : 445-50.

Space Application Centre, Ahmedabad, (2004). All India Wheat production forecasting using multi-date IRS WiFS and weather data for 2003-04 season. RSAM/SAC/FASAL-TD/SN/18/2004.

Vogel, Fred. A. (1985). Crop forecasting methodology current and future procedures in the U.S. Proceedings of the 45th session of the International Statistical Institute, held at Amsterdam : 12.1-1 to 13.1-15.

Working Group, Planning Commission (2001). Report of the Working Group on Crop husbandry, Demand and Supply Projections and agricultural inputs for Tenth Five Year Plan, TFYP Working Group No.43, Planning Commission, Government of India, pp 45-52.

THANKS