Chapter 2

REVIEW OF LITERATURE
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Studies conducted over the period were reviewed and the important literature pertaining to the objectives of the study have been presented systematically under the following heads.

1. Yield gap studies in agriculture in general
2. Studies on uncertainty and risk in agriculture in general
3. Studies on yield gap and uncertainty in sericulture

2.1 YIELD GAP STUDIES IN AGRICULTURE IN GENERAL

‘Yield Gap Analysis’ is a research technique that formally emerged in the early 1970’s. Developed by the international Rice Research Institute (IRRI), it was extensively used to analyse and measure the determinants of gap in yield in different situation pertaining to different crops and regions.

The methodology used by the Centro International de Agriculture Tropical (CIAT) to Evaluate on-farm constraints to higher bean yields in Colombia (Pinstrup-Anderson et. al., 1976) was a type of yield gap analysis that could be applied to situations where researchers have little information about the size of yield reducers. The procedure was based on the collection of data from a representative sample farms. Qualitative and quantitative information was gathered on the yield loss. Coefficients were estimated from a production function which observed that yields were regressed upon factors assumed to influence yield levels. Each regression coefficient multiplied by the mean value of the particular yield-limiting factor provided an estimate of overall impact of the factors in question on yields. The success of such an analysis required observations on at least 30 farms, information on variations in environmental and technological variables and an inter-disciplinary team effort.
The International Rice Research Institute (IRRI) has pioneered a methodology to identify yield gap factors and to estimate the magnitude of their impact on rice production (Gomez, 1977; De Datta et al., 1978; Gomez et al., 1979). The total yield gap was conceptually divided into two parts. Gap-I represented the difference between research station yield and potential farm yield (demonstration plot yield) and was caused by uncontrolled environmental factors. Gap-II was the difference between potential farm yield and actual yield at the farm level and was explained by various biological and socio-economic factors operating at the farm level. The main focus of the IRRI was on yield gap-II. Hence, the factors caused the difference between the potential yield gap was computed as the difference between the potential yield and actual yield. The IRRI methodology thus provided a major improvement in the field of yield gap analysis. Using this methodology with/without some modifications, several studies have been conducted till date. The methodology per se however, did not make a significant contribution towards understanding the underlying socio-economic determinants of yield gaps. It was restricted to identification of the inhibitions and obstacles that came in the way of adopting new technology. The impact of various constraints on the level of yields and their stability could not be properly quantified.

The lack of awareness, costliness of inputs, lack of timely availability of inputs, unsuitable technologies, pests and disease problems, shortage of capital and lack of technological guidance were some of the constraints identified in the study of Rastogi (1977). In view of this, the author suggested that the farmers should be exposed to research recommendations not merely through demonstrations but through their direct involvement by way of performing various agricultural operations.
The factors that prevented farmers from achieving the yield potential of modern rice varieties were grouped under two main heads by De Datta et al., (1978):

(1) Technological or biological constraints which were related to such things as the crop variety, soil type, disease, water management and weeds.

(2) Behavioral or socio-economic constraints related to such things as the farmers' behavior, his knowledge, perception of risk, institutional factors, credit and input supply and distribution.

In a study on absolute maximum food production potential in India, Sinha and Swaminathan (1979) found that there existed a wide gap between yields obtained on demonstration plots and the yields realized on average farms. They estimated that the absolute maximum production of grain equivalent in India would be of the order of 4572 million tons per year. The study concluded that India is endowed with a large untapped production potential, which provided hope for a bright agricultural future in the country.

The main objective of International Rice Agro-Economic Network (IRAEN) research was to measure the yield gap between potential and actual yield in the farmers' fields and to identify the factors responsible for such gaps. In this research work conducted by Barker (1979) and Herdt (1979), the physical and environmental conditions, soil and water control and institutional factors like farm size and tenurial system, were assumed to be given. Fertilizer use and insect control were found to have effect on yield levels to a marked extent.

The National Demonstration average yield of paddy, jowar, maize, wheat and ragi were compared with the national average crop yields by Kahlon (1980) in
his study on agricultural resources and production potential of India. The National Demonstration average yield of paddy, jowar, maize, wheat and ragi were 51.77, 42.95, 34.30, 36.65 and 22.60 quintals per hectare respectively, while the national average yields of the respective crops were 19.76, 7.26, 10.43, 14.77 and 10.95 quintals per hectare. Thus, the yield gaps came to 61.83, 83.09, 69.59, 59.70 and 51.54 per cent respectively for paddy, jowar, maize, wheat and ragi. He observed that higher gap in the yield potential need to be bridged through proper extension network.

Choudhary et.al., (1980) compared the groundnut crop yield obtained by the average farmer under traditional method of farming with that obtained under the improved techniques in Andhra Pradesh region. The study showed that the average yield obtained under improved techniques of farming was 12.5 quintals per hectare, whereas the average realized yield under traditional method was only 6.25 quintals per hectare, thus showing a gap of 50 per cent in yield between the two techniques of farming. It was observed that crop variety, fertilizer, pest and disease problems were the major biological constraints while lack of awareness, traditional belief and non availability of inputs including capital were the prominent socio-economic constraints affecting the actual yields on the farmers’ field.

The drawbacks of the IRRI-type yield gap analysis for farming systems were analyzed by Sarin and Binswanger (1980). They felt that the measurement of gaps in terms of gross returns instead of yields would be more appropriate for farming systems which comprised more than one crop or more than one variety of crops as the computation of yields posed the problem of adding up yields. They further recommended individual crop oriented gap analysis in places where high-yielding genotypes had already been adopted on an extensive scale.
Several studies documented the superiority of the new technology over the old technology. In most of these studies (for example, Deshaiah, 1980; Ghodake, 1981; Rastogi, 1982), economic factors especially capital in particular, emerged as more important than the biological factors, as constraints for adoption and exploitation of the new technology.

Using the IRRI-type of gap analysis, Rao and Prasad (1981) observed the existence of gap in yields obtained from demonstration plots and the yield realized by the farmers for all varieties of paddy. The gap in yield was found to be small in the case of PR 6-17 and Jaya varieties (3.62% and 4.18%), whereas, it was of a very high order for masuri variety (57.78%). Sarup and Pandey (1981) measured the gap between the maximum potential yield and actual farm yield of wheat crop in different states. The estimated yield gap index defined as the percentage of unrealized yield potential which varied from 30% for the state of West Bengal to 75% to that of Karnataka. While the all India index of the yield gap was found to be around 60%. All rather paradoxical phenomenon revealed by this study was that of the state of Punjab, which has the highest wheat productivity in the country, also had a yield gap index of 36.4%. The study thus revealed the existence of considerable untapped yield potential in wheat crop.

Herdt and Mandac (1981) in their study on modern technology and economic efficiency of Philippines rice farmers formulated a model to decompose the total yield gap into three components responsible for this gap namely, profit seeking behaviour; allocative inefficiency and technical inefficiency. They attributed 78% of the yield gap in rice to technical inefficiency. The remaining 22% of the yield gap (0.2 MT/ha) is accounted for profit seeking behavior and allocative efficiency.
In a study on yield constraints of Kharif groundnut in Rayalseema region of Andhra Pradesh, Rao and Prasad (1982) established the dominant role of climatic factors in influencing yield levels on the farmers’ field. They observed a significant difference in the yield levels between farmers’ practices and improved package of practices even under unfavorable conditions.

Ghodake and Walker (1982) catalogued capital constraint, profit-seeking behavior, lack of knowledge about new technology, risk bearing ability, institutional and social infrastructures as factors preventing farmers from realizing the yield potentials on their fields.

Rangaswamy (1982) observed that the yield of jowar on demonstration farms was 20.30 quintals per hectare while that on farmers’ field it was only 13.72 quintals per hectare, thus showing a gap of 32.5 percent. In the case of bajra, the farm potential yield was 11.67 quintals per hectare whereas, it yielded 5.89 quintals per hectare on farmers’ field. Thus, a yield gap of 49.52 per cent was observed.

The ratio of yield on farmers’ plots to that of demonstration plots was used by Rastogi (1982) as an index to measure the yield gaps in respect of different crops over a period of time and at different locations. The yield gap ratio showed wide variations between different crops. Even for the same crops, it varied from region to region and from year to year even in the same region. The variations in yield ratios during different years were attributed to seasonal conditions. The study documented higher yields under demonstrations in all the years and for all the crops, thereby establishing the built-in mechanism of the recommended technology to withstand weather risks. He concluded that, given the infrastructural and institutional support, the recommended technology could help in bridging the potential gap, which varied from 200 per cent to 400 per cent in
Based on the IRRI approach and the discussions held in the All-India coordinated Research Project on Dry land Areas (AICRPDA) and International Crops Research Institute for Semi-Arid Tropics (ICRISAT) working group meeting on yield gap analysis, Ghodake and Walker (1982) attempted to analyze the problem of yield gap in four major steps. The first step pertained to the basic question of whether there was a gap in the yield at all and if so, what its magnitude is? In the second step, the total yield gap was partitioned into two major components. The first component (termed as Gap-I) was attributed to environmental differences and non-transferable component of technology while the second component (Gap-II) was attributed to inefficient cultural practices and sub-optimal input use by farmers. The third step involved the estimation of potential yield and actual yield on farmers’ fields. The fourth step attempted to explain why farmers failed to realize the yield potential. The authors opined that the yield gap analysis in dry land agriculture called for a more flexible approach due to number of reasons.

A sizeable gap between potential yield and actual yield was observed by Kalirajan (1982) while measuring the yield potential of high yielding varieties technology at farm level. He concluded that the deviations in the farmer’s yield from potential yield were due to the failure of farmers to use the best practices, which were not possible under their economic environment. In a study on production potential of food crops in India, Sharma et al., (1983) documented a yield gap of 51.8 per cent and 52.2 per cent in paddy and wheat crops respectively. This implied ample scope for increasing the yield on farmers’ field with the existing level of technology. Similarly, in the presidential address, delivered at the 43rd Annual Conference of the Indian Society of Agricultural Economics (ISAE) at Kanpur, Johl (1984) pointed out that the gap between the

the case of sorghum, pear millet, castor and chickpea. There was scope for raising the yield of other crops as well.
potential productivity indicated by research and the actual performance of different crops on the farmers’ fields ranged between 30 to 65 per cent. Thus, he concluded that even with the available technology and the given cropping patterns in different agro climatic zones of the country, there was tremendous potential for increasing productivity through the application of inputs and better management practices.

The existence of a wide yield gap between complete adoption of new technology and its partial adoption on one hand and between complete adoption and non-adoption on the other in rabi jowar was established in a study by Suryawanshi and Gaikwad (1984) in the drought prone areas of Ahmednagar district. The average potential farm yield of rabi jowar was 7.02 quintals per hectare. The average yield under general farmers’ condition with non-adoption of recommended technology was only 2.12 quintals per hectare, while the yield from partial adoption of technology was 3.42 quintals per hectare. This implied yield gap-I of 3.60 quintals per hectare (difference between the potential farm yield and yield from partial adoption of technology) and yield gap-II of 1.3 quintals per hectare (difference between the yield from partial adoption of technology and yield under farmers condition) and yield gap-III of 4.9 quintals per hectare (difference between the potential farm yield and yield under farmers’ condition). Some of the factors identified as constraints for the non-achievement of potential yields in rabi jowar were: non-adoption of improved varieties, use of lower seed rate, inadequate labour use, higher prices of fertilizers and non-availability of plant protection chemicals.

The main constraints conditioning the yield levels in farmers’ fields in rainfed area of Midhills of India as identified by Arya and Shaha (1984) were: skewedly distributed holdings with small holdings being numerically dominant, sub-divided and fragmented holdings, shortage of labour during peak seasons,
shortage of inputs including capital and lack of education, extension and lack of land treatment for water conservation.

_Fale et al., (1985)_ in a study of rice production in Ratnagiri district, observed a narrow gap of 3.8 per cent (2 q/ha) between yield of experimental station and yield obtained in National Demonstration plots. However, a substantial gap of 56 per cent (29.4 q/ha) was established between potential yields and the actual yields in farmers' fields.

_Panghal et al., (1985)_ estimated the magnitude of gaps in attainable yields using simple statistical tools like means and coefficient of variations in a study on analysis of attainable yield gap in important food crops in Haryana. The study showed that the average realized yield levels of wheat, gram, bajra and rice during the last 16 years were only 44.25, 16 and 47 per cent respectively of the potential attainable yields. It was found that the investment of high capital in modern agricultural technology increased the magnitude of risk of loss substantially. In view of this, it was found that farmers were inclined to adopt new technology for the crops that ensured higher and stable yields.

_Ray and Chahal (1986)_ observed a wide gap between the National Demonstration yield and the actual yield with respect to groundnut. The gap was maximum in the States of Andhra Pradesh (15.89 q/ha), Maharashtra (6.84 q/ha) and Karnataka (5.82 q/ha). Poor management practices like untimely sowing; improper seed rate and use of untreated seeds were responsible for this gap. In view of this fact, they advocated strengthening of the existing extension and training network.

_Subramanya (1986)_ observed that the yield of ragi at the research station was 28.80 quintals per hectare, as against 20.61 quintals per hectare obtained on demonstration plots, resulting in a sizeable yield gap (difference between the
yield obtained at research station and at demonstration plot) of 29.3 percent. The average yield on farms using high yielding varieties was 10.50 quintals per hectare, resulting in an yield gap-II (difference between the demonstration yield and the actual farm yield with high yielding variety) of 49.05 percent, while the average per hectare yield on farms using local variety was only 7.30 quintals, indicating an yield gap-III (difference in yield between the farms using high yielding variety and the farms using local variety) of 30.50 percent. Subramanya (1986) considered the seed variety and nutrients as the biological constraints. Education, institutional participation, farm size and credit availability as socio-economic factors that prevented farmers from attaining the potential yield. The author found that the use of local varieties and lower levels of plant nutrients had largely contributed to the wide yield gap.

Singh and Reddy (1987) estimated the gap between potential and actual yield of castor in southern Telangana Zone of Andhra Pradesh. The actual yield of castor was only 529 kgs. per hectare as against the potential yield of 1637, resulting in a wide gap of 1108 kgs. per hectare between potential yield and actual yield. They stated that even the progressive farmers failed to follow all the recommended practices. They felt that the existing yield levels of castor could be improved to a considerable extent if farmers followed all the recommended practices.

Madhavaswamy and Seshareddy (1987) observed a fairly wide gap in the HYV jowar yields. The study revealed a difference of 7.00 quintals per hectare between the yield of research station and best cultivator. A difference of 13.08 quintals was observed between the yield of best cultivator and average cultivator. The difference between the yield of research station (32.00 q/ha) and that of average cultivator (11.92 q/ha) was estimated at 20.08 quintals per hectare. Lack of suitable variety under rainfed conditions, poor threshability, problem of striga...
(weed), lack of capital and non transfer of technology were found to be the major constraints responsible for the low spread of HYV jower.

**Basavaraja et al. (1989)** attempted to estimate the gap in the attainable cotton productivity in Dharwad and Raichur districts of Karnataka based on the primary data collected from cotton growing farmers and demonstration plot data. Path coefficient analysis was used to analyse the nature of association between gap in the attainable productivity and the sub-optimal input use. The study revealed that there was over 40 per cent gap in the attainable cotton productivity which was mainly attributed to the suboptimal input use. Sub-optimal use of plant nutrients followed by the plant protection chemicals and labour were the most important factors influencing the gap in the attainable productivity.

**Holikatti (1991)** studied the yield gaps in chilli in Karnataka. He found that, the estimated total yield gap in Bydagi chilli ranged from 52.25 per cent in large farms to 52.45 per cent in small farms. The size of the yield gap-1 (difference between research yield and potential farm yield) in chilli was 25.32 per cent, while the size of yield gap-2 was 38.07 per cent which is relatively large. The range of yield gap-2 (difference between potential farm yield and actual yield) was from 36.33 per cent to 38.74 per cent on small farms and large farms respectively.

**Chowdhary et al. (1993)** compared groundnut yield obtained by an average farmer under traditional method of farming and improved techniques of farming in their study on yield gaps in groundnut in Ananthapur region of Andhra Pradesh. The study showed that the average yield obtained by improved techniques of farming was 12.5 quintals per hectare, whereas the realized average yield under traditional method was only 6.25 quintals per hectare. There was cent per cent improvement in groundnut productivity by adopting improved techniques by an average farmer.
Sahu et al. (1993) determined the gap between potential yield and existing yield (local and High Yielding Varieties) in their study on yield gap analysis of paddy production in Jabalpur district of Madhya Pradesh. They found that biological and socioeconomic constraints have more impact on actual production figures than lack of research. The yield gap was greater in the case of local varieties (57.4 per cent) than high yielding varieties (52.4 per cent). The gap widens with decrease in the size of holding in case of HYV. The analysis of input use revealed that in general, farmers were using more than the recommended rate of seed in both local and HYVs.

Pandey and Sarup (1994) in their study on farm investigation into yield gaps and constraints in crop productivity, they conducted an investigation in villages involved in operational research project on pulse production in Mohindergarh district of Haryana. Based on the investigation, they examined the yield potential of various rabi season crops (chickpeas, wheat, barley and mustard) under farm conditions, estimated the extent of yield gap, estimated the relative contribution of limiting factors responsible for the existing yield gaps and examined farmer's perceptions of constraints inhibiting yields. They found that the difference between potential and actual yields was significant for all crops. The yield gap was highest for chickpeas and lowest for wheat. The major biological and agronomic factors contributing to prevailing yield gaps were fertilizer application levels, plant protection measures, use of farmyard manure and seed rate. Farmers' perceptions of constraints limiting attainment of higher yields included water management, non-availability of location-specific drought and pest resistant varieties, lack of technical knowledge and low soil fertility.

Reddy et al. (1996) revealed in their study on economic analysis of yield gaps and constraints in rice production in Guntur district of Andhra Pradesh that the highest yield gap for the period 1992-93 was observed between research station farms and demonstration farms, followed by demonstration farms and
sample farms which were directly related to the farm size. The major factors influencing yield gaps were identified as less use of all input levels except nitrogen on sample farms as compared to the demonstration farms. Therefore, the empirical findings implied that the yield on actual farms could be increased by 50 per cent over existing yield level (36q/ha) by supply of key inputs at subsidized rates, providing the institutional credit at reasonable interest rates specially to small and medium farms, making available irrigation at critical stages of crop growth based on regional crop planning, remunerative output pricing and streamlining existing extension system for efficient transfer of technology. Further, these strategies could also reduce income inequalities among various size group farmers by exploitation of available yield potential to reach the yield level of demonstration farms (54.3q/ha) by tackling various technological, socio-economic and institutional constraints which are specially faced by small and medium farmers.

Sharma (1996) in his study on constraints study of mustard production in Sikar district of Rajasthan showed that there was 27 per cent yield gap between demonstration mustard farms and domestic farms. The main constraints in increasing the production of mustard were lack of technical knowledge, high cost of fertilizers, seed and protection measures, and shortage of money. About 61 per cent of farmers did not have adequate credit facilities.

Siddaramaiah and Gopikrishna (1996) conducted a study on extent of yield gap in cultivation of paddy in Mysore taluk in southern dry zone of Karnataka. The comparison revealed that there was significant difference in the yield gap (between demonstration yield and farmers’ yield) of farmers under canal and tank irrigation systems. The tank irrigation system, which had a mean yield gap of 51.35 per cent, was the least congenial one, while canal irrigation system with a mean yield gap of 35.96 per cent, was the most desirable system for paddy production.
Nagabhushanam and Herle (1997) reported that there was yield gap of 26.11 per cent between progressive farmers and average farmers in the case of paddy. The yield gap was 34.74 per cent between the research station yield and average farmer’s yield. The yield gap between research station and progressive farmers was only 8.63 per cent. Thus, the study concluded that research yield in paddy can be achieved to a greater extent by adopting proper package of practices.

Reddy (1997a) found in his study on differential performance of high yielding varieties of cotton: an economic analysis of yield gaps and constraints in Andhra Pradesh that the yield gap between demonstration farms and sample farms (yield gap-2) was higher than the gap between research station farms and demonstration farms (yield gap -1). The yield gaps were also related to farm size. Large farmers have benefited more from the adoption of technological innovations than small and medium farmers. The major factors contributing to yield gap were the gap in the use of nitrogen, phosphorus, human labour, bullock labour, seeds and excessive use of pesticides. The major constraints in exploitation of yield potential were identified as lack of technical guidance, pest incidence, lack of own capital, high cost of inputs and non-remunerative prices. The results implied that the yield on actual farms could be increased by 50 per cent over its existing level (12 q/ha) by supplying key inputs at subsidized rates, providing technical guidance and institutional credit at reasonable interest rates, making available irrigation water based on regional crop planning, remunerative output pricing, and streamlining the existing extension system for effective transfer of technology.

Reddy (1997b) quantified and analysed the yield gaps and subsequently identified the constraints in his study on differential performance of high yielding rice varieties: yield gaps and constraints in Guntur district of Andhra Pradesh. Higher yield gap was observed between demonstration farms and sample farms.
(gap 2) followed by research station farms and demonstration farms (gap 1). The estimated yield gap function (demonstration farms vs. sample farms) indicated less use of all input levels except nitrogen on sample farms as the major key factor in yield differences. Opinion survey indicated that lack of own capital, non-availability of irrigation water at critical stages of crop growth, incidence of pests, and non-remunerative output prices were considered major constraints in getting improved yields and the reasons behind low yields on farmers' fields. Hence, he revealed that strategies should be formulated to reduce income inequalities among various size group farmers by the exploitation of available yield potential to reach the yield level of demonstration farms (54.3 q/ha) by tackling various technological, socioeconomic and institutional constraints.

Gaddi (1999) in his study on yield gaps and constraints in production of major crops in North Karnataka- an economic analysis observed that the magnitude of total yield gap in jowar, groundnut and cotton was 1454.20 Kg, 1849.14 Kg and 1526.30 Kg per hectare. He also showed that the indices of yield gap were 58.83 per cent, 57.43 per cent and 56.55 per cent for jowar, groundnut and cotton respectively.

Gaddi et. al. (2002a) in their study on yield gaps and constraints in the production of rabi sorghum in Karnataka: a path coefficient analysis, revealed a magnitude of total yield gap of 1454 kg/ha. Farmers realized 58.83 per cent of potential yield. Path coefficient analysis showed that the suboptimal use of plant nutrients, human labour and bullock labour on farmers' field vis-a-vis demonstration plots were the major factors conditioning yield gap. Substandard and costly chemical fertilizer and plant nutrients, labour shortage, non-availability of desired variety seed, unfavourable climatic conditions and incidence of pest and diseases limited sorghum productivity in farmers' fields.

Gaddi et. al. (2002b) reported a total yield gap 1526.30 kg/ha in cotton,
which comprised a relatively higher Yield Gap-I (893.50 kg/ha) than Yield Gap-II (632.80 kg/ha) in their study on yield gaps, constraints and potential in cotton production in North Karnataka - an econometric analysis. The index of yield gap, index of potential yield and index of potential farm yield were 56.55 per cent, 43.45 per cent and 65 per cent, respectively. Decomposition analysis revealed that among the different sources contributing to Yield Gap-II (42.45 per cent), differences in the cultural practices between the farmers' field and the demonstration plots explained 28 per cent, while the suboptimal input was 15 per cent. Shortfall in the use of human labour and bullock labour were the greater portion of this gap. Among the large farmers non-availability of labour, incidence of pest and diseases, non-application of chemical fertilizers at the recommended level, non-availability of recommended variety and genuine seeds were the major constraints in cotton production.

**Naidu and Hunsagi (2003)** in their study on sugar cane yield gap analysis, production trends and fertilizer use by farmers in major sugarcane growing agro climatic zone of Karnataka, compared recommended agronomic package with farmers’ current practices and obtainable cane yield at research farms and farmer’s field. They observed wide gaps specifically with regard to fertilizer use (amount and ratio). The gap varied from 4.5 to 42.2 ton per hectare in different agro-climatic zones. The gap was lowest (4.9 ton per hectare) on Chikkodi soils while it was highest (42.2 ton per hectare) on Jamkhandi soils. The obtainable cane yield differences are of intermediate level i.e. 23.3 ton per hectare on Bidar soils, 29.1 ton per hectare on Mandya soils and 33.7 ton per hectare on Bhadravathi soils.

**Lambert Dayton (2004)** compared four spatial regression models for yield monitor data (Argentina). The gap between data analysis and site-specific recommendations has been identified as one of the key constraints on widespread adoption of precision agriculture technology. This disparity is in part
due to the fact that analytical techniques available to understand crop GIS layers have lagged behind development of data gathering and storage technologies. Yield monitor, sensor and other spatially dense agronomic data is often autocorrelated and this dependence among neighboring observations violates the assumptions of classical statistical analysis. Consequently, reliability of estimates may be compromised. Spatial regression analysis is one way to more fully exploit the information contained in spatially dense data. Spatial regression techniques can also adjust for bias and inefficiency caused by spatial autocorrelation. The objective of this paper is to compare four spatial regression methods that explicitly incorporate spatial correlation in the economic analysis of variable rate technology: (1) a regression approach adopted from the spatial econometric literature; (2) a polynomial trend regression approach; (3) a classical nearest neighbor analysis; and (4) a geostatistical approach. The data used in the analysis is from a variable rate nitrogen trial in the Córdoba Province, Argentina, 1999. The spatial regression approaches offered stronger statistical evidence of spatial heterogeneity of corn yield response to nitrogen than ordinary least squares. The spatial econometric analysis can be implemented on relatively small data sets that do not have enough observations for estimation of the semivariogram required by geostatistics. The nearest neighbor and polynomial trend analyses can be implemented with ordinary least squares routines that are available in GIS software. The main result of this study is that the conclusions drawn from marginal analyses of this variable rate nitrogen trial were similar for each of the spatial regression models, although the assumptions about spatial process in each model are quite different.

Ahuja et al. (2005) in their study on yield gaps and constraints in the production of mung and moth bean in arid Rajasthan, revealed a total yield gap of 300 kg/ha for mung bean and 250 kg/ha for moth bean. In mung bean, farmers realized 57.14 per cent potential yield and 61.84 per cent potential farm yield,
while in moth bean farmers realized 60 per cent and 75 per cent, respectively. Constraints analysis categorized into production and socioeconomic constraints revealed that production losses (70 per cent for mung bean and 55 per cent for moth bean) were maximum due to insects/pests attack in both the crops. High cost and non-availability of high-yielding-variety seeds were the major socioeconomic constraints in arid region.

Angadi and Yaragattikar (2005) in their study on identification of research gap in intercropping systems under rainfed condition in Dharwad district of Karnataka found that non application of organic manures, imbalanced row ratio, non addition/ replacement of plant nutrients and competition for resources like nutrients, soil, moisture and light were four major factors/ constraints quoted by the farmers for declining yield in turn causing yield gaps.

Singh (2005) in his study on yield gap in arid land crops of Thar Desert of Rajasthan, reported that there was no difference in yields of arid land crops grown by different categories of farmers (marginal, small and large farmers). Moreover, the difference between the actual yield obtained by farmers and that obtained at the research station suggests that there is great potential to increase crop yield. He also reported that priority should be given to educate the farmers about improved agriculture practices to bridge the wide gap between the yields of research station and that of the farmers' fields.

Bhatia et. al. (2006) analysed yield gap in important legumes in India using simulation models. They considered district average yield as the farmers' yields. Based on these data, the yield gaps between potential and achievable yields (YG I), between achievable and farmers' yields (YG II) and total yield gaps between potential and farmers' yields were estimated. The farmers' average crop yield was 1040 kg per ha for soybean, 1150 kg per ha for groundnut, 690 kg per ha for pigeon pea and 800 kg per ha for chickpea in India. Large spatial and temporal
variability was observed in the yield gaps of the 4 legumes across the production zones. Total yield gap for the production zones ranged from 850 to 1320 kg per ha for soybean, 1180 to 2010 kg per ha for groundnut, 550 to 770 kg per ha for pigeon pea and 610 to 1150 kg per ha for chickpea. Finally, they concluded that YG II formed a significant part of the total yield gap of the 4 legumes, indicating the need to scale-up the improved crop production technologies from on-farm demonstration sites to farmers in the production zones.

Liang Weili et. al. (2006) revealed that yield of winter wheat on the demonstration farms could exceed 9000 kg per ha, which was much higher than that achieved in most of the farmers' fields, where the average yield was only 69 per cent of that of the demonstration plots. Over seeding, untimely sowing, confusion in cultivar use and poor irrigation practice together with unbalanced fertilizer application, were the major technical problems responsible for the yield gap. The crop yield in farmers' fields could be increased by 43 per cent through improving field management practices without additional costs, while resulting in an extra net profit of 4748 yuan per hectare.

Sharma et. al. (2008) studied the yield gap and technical efficiency with respect to cereals production in Himachal Pradesh. They adopted frontier production function for analysis of technical efficiency. It has been found that the average yield of all the major cereal crops is below the national average, except the maize crop which has been found surplus in the state. The mean technical efficiencies have revealed that a considerable portion of frontier output is found untapped. The ratio of marginal value productivity (MVP) and marginal factor cost (MFC) has been found to be more than one in case of 50 per cent inputs for all the crops. The analysis has also revealed that a majority of the farmers operate at lower efficiency level due to practicing of traditional cultivation methods.
Woonho Yang et al. (2008) studied the yield gap between dry and wet season rice crop grown under high yielding management conditions. Field experiments were conducted in the dry season (DS) and the wet seasons (WS) of 2003 and 2004 at the experimental farm of the International Rice Research Institute (IRRI), Los Banos (14°11’ N, 121°15’ E and 21 m elevation), the Philippines. Six genotypes recently developed by IRRI were used in the study. Rice grain yield highly varies depending on cropping seasons under the tropical irrigated conditions. The study aimed to (i) compare the grain yield or rice in dry season (DS) and wet season (WS) and (ii) determine climatic and physiological factors critical to the yield gap between DS and WS. Six genotypes, two each for indica inbred, indica/indica F1 hybrid and the second-generation new plant type were grown in DS and WS of 2003 and 2004. Significantly higher grain yields were achieved in DS than in WS by 94 per cent for 2003 and 35 per cent in 2004. Mean daily radiation was higher in DS than WS. The greater radiation during ripening in DS contributed to the higher grain yield.

Dhandhalya and Shiyani (2009) studied the production potentials, yield gaps and research prioritization of production constraints in oilseed crop in Saurashtra region of Gujarat state. They adopted the methodology followed by International Rice Research Institute to estimate the magnitude of the yield gaps and identification of the constraints. They studied the biotic and abiotic constraints resulting in the yield loss in oilseeds in Saurashtra. More attention towards watershed development, drip irrigation system, soil fertility management, regular power supply and strengthening extension services are the major suggestions emerged from the study.

Nirmala et al. (2009) studied the yield gap in rice in Raichur district of Karnataka State. They found that the potential yield at research station was 6.5 MT/ha while at the demonstration site, the potential farm yield was reported to be 5.69 MT/ha. Yield gap I which explains the untapped potential yield
accounted for 12.46 per cent. The yield gap II which was the difference between the potential demonstration yield and the actual yield accounted for 11.82 per cent. Among the major constraints for rice production, labour shortage ranked first followed by lack of remunerative price, pest and disease incidence and untimely release of canal water. Imbalanced use of fertilizers, non-availability of agricultural machinery, small size of the farm, weed infestation, tenancy problems, non-optimal plant population, nutritional disorders, late transplanting, natural calamities, salt affected soils and poor organic matter status of the soils were hindering factors in realization of potential yield.

2.2 STUDIES ON UNCERTAINTY AND RISK IN AGRICULTURE IN GENERAL

Uncertainty is one where neither the event nor its probability of occurrence is known. Risk on the other hand is a group measure where individual uncertainties are pooled together to obtain an estimate of risk for the group of similar individuals who are all similarly exposed. The studies conducted on uncertainty and risk in agriculture in general having some relevance to the present study have been presented here.

Knight (1921) for the first time distinguished measurable uncertainly or risk from immeasurable uncertainly. In simplest terms, the risk is associated with probabilities of various outcomes. While uncertainly cannot be specified with probabilities. Indeed one cannot practice or act rationally without summarizing information in the form of a probability distribution.

Freund (1956) used the first programming model with risk in agriculture. He assumed that the net returns associated with each alternative are normally distributed. He selected an exponential type of utility function and derived optimum mix of crop and livestock systems for North Carolina country.
Many researchers opined that risk in agriculture is mainly due to uneven rainfall, fertility of land, pests and disease attack, uncertainly with respect to prices, lack of adequate storage facilities and other natural factors (Sen 1964; Randhawa and Heady, 1963; Mishra 1964).

Hazell (1971) noted that the quadratic decision criteria for farm planning are theoretically appealing but difficult to handle computationally. He developed a linear alternative, while retaining most of the described features of the quadratic model. It can be solved with conventional linear programming technique. He substituted mean absolute deviation for variance as a measure of dispersion.

Hiebert (1974) indicated that risk accession is associated with the use of less land and less fertilizer in production of the crop than its risk neutrality. The probability of adoption increases with the stock of information pertaining to the production through extension contact. More favorable environment increases the expected income from modern production methods and hence increases the probability of a farmer adopting the new technology.

Ability to adopt new technology is the source risk internal to the farm business. The external sources of risks in agriculture are prices, yield risk, technology level, legal and institutional frame work, changing fiscal policies, etc. (Rajgopolan and Varadarajan, 1978).

Mruthyunjaya and Sirohi (1979) used MOTAD to work out efficient sets of farm plans for small and large farms in Bijapur district, a typical drought prone area of Karnataka. Input-output co-efficient for traditional farm enterprises and dairy enterprises were worked out from a sample of 113 farms and the recommended enterprises were taken from research institutions. The input optimization, better farm technology, credit, bullock labour, land utilization, farm
returns and employment were studied by comparing the existing plans through the parametric linear programming.

**Pervaiz Amir (1982)** evaluated risk and uncertainty research in relation to crop varietal development. In his paper, he has reviewed various methodology and statistical tools to analyse risk and uncertainty in varietal evaluation. He also collected data from three rainfall zones in Syria. The data were collected from 168 barley farmers. He found out that small farmers consistently change their input decisions in a step wise fashion as more information becomes available. If there is heavy rainfall he will change his strategy for weeding or pesticide use. The emphasis in risk and decision theory is more on formulation of expectation models, derivation of farmer utility functions under different expected utility assumptions.

**Just and Zilberman (1983)** showed whether modern inputs are risk increasing or decreasing using production function approach. The results also demonstrate that correlation of out puts under alternative technologies plays an important role in determining adoption rates.

**Singh and Jain (1983)** generated normative plans using profit maximizing L.P and MOTAD for different categories of farmers in Ludhiana District of Panjab state, India. He found that all farmers were operating at comparatively high risk. The crop mix was observed to reduce variability in the farm. He further opined that MOTAD was found to be a better technique compared to other for examining risk return trade off. Target MOTAD maximizes mean income subject to a limit on the total negative deviation measured from the fixed target rather than mean.

**Bende (1991)** reports that the existing farm plans regardless of the farm size category were sub-optimal in the semi arid tropical regions of India. The
existing cropping pattern shows that farmers try to maximize farm income and minimize risk by striking a balance between higher income farm enterprises with low risk enterprises. Farmers often find themselves a choice between alternatives in an uncertain environment. They in fact consider riskiness as well as expected return of the option in decision making.

Appelbaum (1991) provided an empirical framework to analyse the effects of uncertainty on firm’s behavior. In particular, they provided a model which can be used to calculate productivity growth for firm facing uncertainty. The model can also be used to decompose total factor productivity into various components and identify the contributions of price uncertainty and risk aversion to productivity growth. In applying the model to the US textile industry, the author used a nonparametric method to estimate output price uncertainty.

Joy Harwood et. al. (1999) in his report submitted to USDA on ‘Managing Risk in Farming’ has given the details of concepts, research and analysis of risk in farming. The authors have utilized the data of different surveys conducted by USDA in USA during the post 1996 Farm Act with the shift towards less government intervention. He has analysed important aspects such as the crop insurance, diversification, futures contracts, leasing, leveraging, liquidity, live stock insurance, marketing contracts, options contracts, production contracts, revenue insurance and vertical integration. He has also analysed the farmers’ reported use of risk management strategies. The report provided a rigorous yet accessible description of risk and risk management tools and strategies at the farm level. It also provides assessments of the risk faced by the farmers, their use of alternate risk management strategies and the changes they make when faced with financial difficulty. It also compares price risk across the crops and time periods and provides detailed information on yield variability.
Wen Ji and Matthew Holt (2000) examined the effects of price uncertainty on agricultural productivity. They applied Appelbaum (1991) empirical framework (model) to analyse the effects of uncertainty on firm behaviour. The authors apply the model to the US agricultural sector using a parametric rather than a nonparametric approach to obtain the measurement of price uncertainty and risk. Agricultural productivity growth under price uncertainty was calculated. The results showed that price uncertainty had a small but significant effect on productivity growth.

Ashok Kumar et. al. (2002) studied the extent of profitability and risk in pulses and oilseeds vis-à-vis cereals and vegetables and also formulates risk efficient farm plans and strategy to reduce risk and augment income through increased area and productivity. Data were collected from 150 farms of Nagrota Bagwan and Kangra development blocks of Kangra district of Himachal Pradesh during seven agricultural years ending 2001. Study revealed that in the case of vegetables and miscellaneous crops the percentage of gross margin is more than the percentage of area, there by showing their high profitability. In the case of cereals, pulses and oil seeds, the percentage of gross margin is less than the percentage area allocated to them, indicating their low profitability. Among pulses, gram yielded the highest returns whereas, among oil seeds, sesame gave the highest net returns. The cereals, pulses and oilseeds stand nowhere in comparison to the profitability of vegetable crops. Cereals have comparatively less risk in terms of area, productivity, prices and gross returns. In the case of vegetables, the magnitude of price risk was higher in the case of lady’s finger, followed by radish, cabbage and cucumber. The farm plans were planned for gross margins of Rs. 45,000 and were given an interval of Rs. 15,000 each. There is scope for increasing existing gross margins of Rs. 70,450 to Rs. 90,000 by re-allocating area under different crops. The total cropped area and cropping intensity showed a continuous increase with the increased level of gross margins.
The optimized gross margin of vegetable farms increased from Rs. 90,000 to Rs. 1,04,000. It is noticed that dairy enterprise reduced the risk and increased returns. The vegetable farming involved greater risk than vegetable plus dairy farming. It is suggested that the vegetable plus dairy is the most appropriate choice for the farmers in the study area. It is also suggested that if these eco-friendly crops are to be retained to promote human health, the productivity and profitability has to be further enhanced through research efforts.

Constantinos Katrakilidis and Nikolaos Tabakis (2004) in their study on ‘Macroeconomic uncertainty and sectoral output performance: empirical evidence from Greece’ provided an empirical investigation of the links between macroeconomic uncertainty and sectoral output using Greek data. Uncertainty is considered in three distinct components, namely the inflation uncertainty, the exchange rate uncertainty and the output uncertainty. The results highlight the differences in sectoral responsiveness and the importance of a stable macroeconomic environment.

Bokusheva et. al. (2006) investigates production risk and technical inefficiency as two possible sources of the production variability that characterised Russian agriculture during the last decade. The empirical analysis is conducted using panel data from 1996 to 2001 on 443 large agricultural enterprises from three regions in central, southern and Volga Russia. A production function specification accounting for the effect of inputs on both risk and technical inefficiency is found to describe production technologies of Russian farms more appropriately than the traditional stochastic frontier formulation.

Jean-Paul Chavas (2006) analysed agricultural economics under production uncertainty. The study explores the economics of input decision by a firm facing production uncertainty in agriculture. It relies on state-contingent approach to production uncertainty. First, the paper develops methodology to
specify and estimate cost minimizing input decisions under a state-contingent technology. Second, the analysis is applied to time series data on US agriculture. It reveals strong empirical evidence that, in the analysis of input choices, expected output alone does not provide an appropriate representation of production uncertainty. The results provide empirical support for an output-cubical technology. This indicates that an ex-post analysis of stochastic technology appears appropriate. The analysis also provides evidence that the cost of facing adverse weather conditions has declined in US agriculture over the last few decades.

2.3 STUDIES ON YIELD GAP AND UNCERTAINTY IN SERICULTURE

Vilas Kulkarni (1993) in his study on yield gap analysis of bivoltine (NB₁D₂) cocoon production in Mandya district found that the yield gap-I (between experiment station yield and potential farm yield) and yield gap-II were 30.26 per cent and 19.62 per cent, respectively. The yield gap-I was attributed for the environmental conditions and other infrastructural facilities available in the multi-location trials and yield gap-II was attributed for non-adoption of recommended package of practices.

Ramanuja Rao et al. (1996) studied the yield gap of cocoon crops in Karnataka. They compared the yield levels at the research station with that of different categories of farmers (small, medium and big farmers). They found that the partial adoption of improved technologies results in poor performance of silk worm crops at farmers’ level. Irrespective of area, yield gap was more in the case of small farmers. Similarly, Subba Rao et al. (1997) studied the yield gap in Tamil Nadu. They also found that yield gap reduced with the scale of farming.

Kumaresan and Vijaya Prakash (1999) studied the risk taking behavior of sericulturists which was quantified using safety first criterion. The data were
collected from Salem taluk of Salem district and Gobichettipalayam taluk of Erode district from a sample of 60 farmers during the year 1998-99. Majority of the farmers were found to be moderately risk averters. The socio-economic variables namely, family size and off-farm income adversely influenced the risk taking behavior of the sericulturists. Risk adapting behavior did not influence the usage of labour and fertilizers in cocoon production. However, risk taking behavior had significantly influenced the disinfectant use in cocoon production. Credit had significant impact on labour use in cocoon production. He concluded that the credit supply could be improved in sericulture for increased input use so as to improve the sericulture productivity.

Rajagopal Reddy and Venugopala Reddy (2000) in their report on the strategic decision making for risk management in sericulture have been analysed. The factors affecting uncertainty has been critically studied. The authors suggested the measures for decision making during uncertainties. The authors opine that the uncertainties cannot be controlled but one has to have the knowledge of these uncertainties so as to manage and exploit the potential of sericulture.

Kumaresan et. al. (2001a) evolved the optimal crop planning with trade-off between risk and return by integrating crop dairy and sericulture enterprises in minimization of total absolute deviation (MOTAD) framework. The data were collected from 30 randomly selected farmers practicing agriculture, sericulture and dairy activities from six villages in Salem taluk of Salem district in Tamil Nadu during 1998. Five optimal plans with dual objectives of minimization of risk and attainment of expected revenue were developed for an average farm size of 3.7 acres. The model did not recommend the fodder crops and summer crop of paddy in the optimal plans. The area under mulberry was constant throughout all the plans. Thus, the normative plans developed suggested changes in the existing plans so as to minimize the risk and obtain the stable income. Further,
Kumaresan and Vijaya Prakash (2001b) in reviewed risk and uncertainty in sericulture. They opine that risk and uncertainty are important constraints in sericulture. Risk affects the production decisions of the farmers resulting in inefficiency in allocation of resources in farm activities. Hence, it is necessary to incorporate risk in farm planning in agricultural production to evolve more realistic plans.

Barah, et. al. (2003) analysed the yield gap and constraints in muga culture in the Northeastern region of India. They found that the muga culture is a crop reared under wild conditions and are affected by various factors not under the control of the tribal population. The domestication at earlier stages and releasing the well grown larvae may help to combat certain diseases but the worms do not suddenly adapt to new environment and their ability to fight would come down. Hence, they suggested certain repellants need to be used which do not affect the muga worms. Further, they suggested peak seasons of pest attack.

Venkataramana et. al. (2003) in their study on potentials of improved mulberry leaf and silkworm cocoon production technologies in Telangana Region (A. P.) - an assessment through field demonstrations, showed that leaf yield was 30,371 kg/ha per year during 1998-99 and 31,526 kg/ha per year during 1999-2000, compared to the benchmark yield of 20,772.80 kg/ha per year. Silkworm cocoon yield was 51 kg/100 disease-free layings (dfIs) during 1998-99 and 51.75 kg/100 dfIs during 1999-2000, compared to the benchmark yield of 27.27 kg/100 dfIs. Results indicate that the leaf yield showed an increase of 48.13 per cent in 1998-99 and 51.74 per cent during 1999-2000 compared to the benchmark yield before the start of the demonstration. The use of the improved technology was found to be highly productive. Additional net returns per 100 DFLs of Rs. 2978.75 in 1998-99 and Rs. 3316.95 during 1999-2000 were observed.
Kumaresan et al. (2004) studied the yield gaps and constraints in cocoon production in Kolar and Chitradurga districts of Karnataka. They studied the yield gap in K2 (M5) variety of mulberry and the cross breed (PMxNB4D2) race of cocoon. It was estimated that the yield gap in mulberry was 25.49 per cent and 27.05 per cent in mulberry leaf production in Kolar and Chitradurga districts respectively. The total yield gap in cocoon production was estimated to be 42.91 per cent in Kolar and 38.19 per cent in Chitradurga district. Inadequate and improper use of inputs may be one of the reasons for the existence of yield gap.

Deepa and Sujathamma (2005) conducted a sericulture yield gap study in Madanapalle division of Rayalseema Region in Andhra Pradesh in 6 mandals i.e. Molakalacheruvu, B. Kotha Kota, Kurabala Kota, Tamballapalle Punganur and Palamner. A total of 180 sericulturists were interviewed using pretested questionnaire during 2004-05. Data collected on perception of improved technologies by the sericulturists and comparative harvest data of CSB, DOS and LSP source of DFLs month wise and area wise for the five consecutive years from 2000 to 2005 were analysed to find the gaps in cocoon yield and constraints responsible for the yield gap. The field yield was compared with laboratory yield of 55 Kgs / 100 dfls and the potential yield of 70 Kgs per 100 dfls. ANOVA clearly showed that yield obtained from CSB source is higher compared to that obtained by DOS and LSP in Madanapalle Division and the average yield obtained in command area of Madanapalle, Molakalacheruvu and Palamaner was 52.13 Kgs, 52.41Kgs and 55.63 Kgs respectively. Thus there is a gap of 17.87 Kgs, 17.59 Kgs and 14.37 Kgs per 100 DFLs in the field. The findings of the study throw light on the extent of perception of recommended technologies by sericulturists and the factors responsible for yield gap and the strategies to be adopted.

Vijaya Prakash and Dandin (2005) analyzed the magnitude of the yield gaps in mulberry as well as cocoon production and explored the possibilities of relaxing existing constraints in order to bridge the attainable yield gaps. The data
were collected from randomly selected 75 farmers from Mandya district in Karnataka. The results showed that the magnitude of yield gap was 30.01 per cent in the case of small level production and 45.56 per cent with respect to large farmers, which means that about 30-45 per cent of cocoon yield could be increased with the technology package adopted by the demonstration farmers. While analyzing the major constraints for bringing down economically recoverable gaps, it was found that the crucial inputs such as quality mulberry leaf, disinfectants, human labour and mountages were significantly influencing the bivoltine cocoon production.

Lakshmanan (2007) studied yield gap in mulberry sericulture in Mandya district of Karnataka during 2003. The study revealed that potential yield realization was 92.77 per cent in K2 variety of mulberry 76.08 per cent in V1 variety. The reason for not attaining potential yield in V1 variety was due to non-application of recommended inputs. Potential yield realization was higher in multivoltine cross breed (92.86 per cent) compared to Bivoltine cross breed (87.50 per cent). The author suggested for proper adoption of recommended practices for new races and hybrids to attain potential production.

Many studies on yield gap have been attempted in different crops in general and sericulture in particular which have mainly used the methodology that is being followed by the IRRI model. The present study has attempted to analyze the yield gap on similar lines with certain modifications. Majority of the studies compared the yield levels of research, demonstrations and the actual farmer yields. In the present study instead of demonstration yield trials, the attainable yield levels expressed by the farmer are taken into consideration. Further, in this study a special component of yield uncertainty in the total yield gap was analyzed using anticipated yield and the actual yield. ANOVA was employed to assess the statistical significance between attainable, anticipated and actual yield levels. The yield uncertainty was further analyzed using
production function model and the technological decomposition model. Apart from yield uncertainty, crop uncertainty (crop failures) and price uncertainties were also studied. The direct and indirect effects of different inputs in sericulture were analysed using path coefficient analysis to address the reasons for the yield gap. The knowledge and adoption of different technologies / innovations were also studied and the reasons for different uncertainties were studied and analysed.