

DEMAND, DIFFUSION, ECONOMICS AND IMPACTS OF RESOURCE CONSERVATION TECHNOLOGIES IN EASTERN UTTAR PRADESH



AN INSTITUTION OF NATIONAL IMPORTANCE ESTABLISHED BY AN ACT OF PARLIAMENT

THESIS

Submitted in partial fulfilment of the
requirements for the degree of

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in

Agricultural Economics

Submitted by

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Supervisor

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2015

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Dedicated

to

My Dear Brother

Kshitij Gangwar

*Who is not with us now but his memories will always remain
in my heart. I know your full support and wishes are with me.
I will miss you always. "Love you Bhai"*

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I, **Arpita Gangwar**, research scholar under the Supervision of **Prof. Rakesh Singh**, Department of Agricultural Economics, Institute of Agricultural Sciences, Banaras Hindu University, give undertaking that the thesis entitled “**Demand, Diffusion, Economics and Impacts of Resource Conservation Technologies in Eastern Uttar Pradesh**” being submitted by me for the degree of Doctor philosophy is a record of first hand research work done by me during the period of study.

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**Demand, Diffusion, Economics and Impacts of Resource
Conservation Technologies in Eastern Uttar Pradesh**

**Thesis submitted to Department of Agricultural Economics,
Institute of Agricultural Sciences, Banaras Hindu University, Varanasi
in partial fulfilment of the requirements for the degree of**

**DOCTOR OF PHILOSOPHY
in
AGRICULTURAL ECONOMICS**

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Success usually comes to those who are too busy to be looking for it

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Date: August, 2015

Place: Varanasi

(Arpita Gangwar)

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LIST OF ABBREVIATION

CA	Conservation Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CO ₂	Carbon Dioxide
CT	Conservation Tillage
EIAR	Ethiopian Institute of Agricultural Research
Ha	Hectare
IARI	Indian Agricultural Research institute
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IGP	Indo-Gangetic Plains
No.	Numbers
OF	Organic Farming
RCTs	Resource Conservation Technologies
RWC	Rice Wheat Consortium
SAPs	Sustainable Agricultural Practices
ZT	Zero Tillage

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PREFACE

Since, this research work carried out as Ph.D. thesis for doctoral degree in Agricultural Economics in primarily to find out the Demand, Diffusion, Economics and Impacts of Resource Conservation Technologies in Eastern Uttar Pradesh. I hope its results will be of interest to economists and other agriculturists for busting the sustainable production of wheat crop and save cost and environment in future use.

The work describe in the thesis was carried out between October 2011 to July 2015 at Banaras Hindu University under supervision of Dr. Rakesh Singh, Professor, Department of Agricultural Economics, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

Chapter I : The introduction part which provides much of the general information about the RCTs. This chapter justified the need for choosing this research topic and objectives of the research work.

Chapter II : The review of literature deals with the important work done in the past which provides a conceptual framework for carrying out as well as understanding the outcome of present work.

Chapter III : The research methodology explains the methodology for carrying out the research work describing the methods of statistical analysis.

Chapter IV : The description of study area deals with the general information about study area and also status of infrastructure in the study area.

Chapter V : The results and discussion explain the results obtained with appropriate reasons.

Chapter VI : The summary and conclusions gives the description of research work in brief.

In the last, the consulted references during the course of investigation have been cited.

(Arpita Gangwar)

INTRODUCTION

1.1 Background of study

The Green Revolution is one of the most striking success stories of post-independence India. The success was reflected through more efficient dry matter partitioning to reproduction and therefore, higher harvesting index with significant gain in the yield potential. It is the combination of Green Revolution varieties and their responses to external inputs, which produced meaningful advances in agricultural productivity (Pingali, 1999). Because of Green Revolution, there is an increase in food availability without using the extra land resources. Not only varieties which transformed the food production scenario, but the response of these varieties to external inputs brought about a major change in the food production.

India has not only achieved self-sufficiency in food grains but also disproved all good intentioned projections about the food situation, in the world. Paul Eldrich, a noted economist, predicted in 1966 that sometime between 1970 and 1985 the world would undergo vast famines and hundreds of million people would starve to death. His dispassionate analysis indicated that food and population imbalance was hopeless and hence suggested that the United States should announce that it would no longer ship food to countries such as India. However, the Green Revolution in India increased the food grain production from 50 million tonnes in 1951-51 to 133.0 million tonnes in 1980-81 and proved the prediction wrong. An impressive current food grain production level of 251.12 million tonnes (2014-15) is a testimony of the concerted efforts of farmers, scientists and extension workers. Though significant strides have been made for total food grain production, Indian agriculture is still facing second generation problems comprising soil fatigue due to intensive cultivation, saturation of high yielding varieties in terms of yield, continuous decrease in the input use efficiencies, a declining water table and a virtual halt in further expansion of the irrigated area. These issues have been posing a major challenge of maintaining higher production levels without endangering the environment. Wheat

and rice account for more than 50 per cent of the world cereal production, and in combination contribute to the grains for about 20 per cent of the world population. In South Asia, rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L. emend. Fiori and Paol) crops sequence is the largest agriculture production system and occupies about 13.5 million ha area including 30 million ha in India, extending from Indo-Gangetic plain to Himalayan foothills. In India, approximately 23 per cent and 40 per cent of total rice and wheat area, respectively, is represented by rice-wheat system alone (Timsina and Connor, 2001), which requires contrasting edaphic conditions. The Green Revolution boosted the productivity of rice-wheat systems through the introduction of high-yielding varieties and complementary technologies like irrigation and fertilizer in a supportive policy slowdown in productivity growth (Kumar et al., 2002, Byerlee et al., 2003).

The Green Revolution has slowed sharply, as has yield growth, since the 1980s. The slow down or even reversal has been due to water table lowering because of ever deeper tube wells, micronutrient depletion, mono-culture, reducing biodiversity and build-up of insects, diseases and weeds, development of resistance against pesticides and high concentration of pesticides or fertilizer-derived nitrates and nitrites in water courses. The above factors add to the cost of cultivation and, therefore, a decline in the total factor productivity. With the rise in input cost, the net profit of farmers has fallen even if the productivity is increasing slightly. Each farmer, therefore, needs to maximize earnings through alternate technologies specially cost reducing technologies.

From sustainability and profitability point of view, it will be important to conserve the natural resources. In recent years, decline and deterioration of natural resources has emerged as a serious concern for sustainable food production in our country. Optimization of the use of natural resources, inputs and diversification/intensification of cropping system through use of fallow lands/rice fallows are the major issues for conservation agriculture and sustainable agriculture development. The conventional mode of agriculture through intensive agricultural practices was successful in achieving goals of production, but simultaneously led to degradation of natural resources. Conventional practices interpreted here as the

farmer's conventional land preparation practices for wheat, which typically implies intensive tillage with multiple passes of the tractor to accomplish plowing, harrowing, planking, and seeding operations. Reduced tillage often uses a tractor-drawn seed drill – sometimes the same zero-till drill used for zero tillage – but still retains some minimal tillage prior to seeding (often 1–2 tractor harrow passes).

1.2 Conservation agriculture

Conservation agriculture has come up as a new archetype to achieve goal of sustained agricultural production. It is a major step toward transition to sustainable agriculture. Conservation agriculture is vital to safe and healthy natural resources as well as a mean to improved agricultural and rural livelihoods. Resource Conservation Technologies (RCT), therefore, have become a critical component to sustainable growth in agriculture. These technologies require complementary innovations, farmer's participatory approach. This is important because the livelihood of more than a billion agricultural populations in developing countries will depend on technologies that raise outputs per labour-hour and per unit area at less cost (Lipton, 2004).

Globally, the total area under conservation agriculture was 45 million ha in 1999 which increased to 95 million ha by the year 2005. In 2008, total area under conservation agriculture was 105 million ha. Out of this, the share of different continents was 49.58, 40.07, 12.16, 2.53, 1.15 and 0.37 million ha for South America, North America, Australia & New Zealand, Asia, Europe and Africa, respectively (Derpsch and Friedrich, 2009 as cited in Singh et al., 2010). In India, presently more than 2 million ha area in Indo-Gangetic Plains under rice wheat system is under resource conserving technologies (Singh et al., 2010). With the rapid expansion of wheat zero tillage in the Indo-Gangetic Plains, there has been within that region a outpouring of interest in resource conserving technologies.

1.3 What are Resource conservation technologies and Conservation agriculture?

Resource conserving technologies refers to those practices that enhance resource or input-use efficiency. Zero or reduced tillage practices that save fuel and

improve plot-level water productivity may also be considered RCTs, as may land levelling practices that help save water. There are many more examples like laser leveling, mulch tillage, cover cropping, etc. agricultural technologies that can save resources reduce production costs and improve production while sustaining environmental quality are therefore becoming increasingly important (Hobbs and Gupta, 2003).

In contrast, conservation agriculture practices only refer to the RCTs with the characteristics like, Soil cover, particularly through the retention of crop residues on the soil surface; Sensible, profitable rotations; and a minimum level of soil movement, e.g., reduced or zero tillage.

The distinction is important because some RCTs, while attractive in the near-term, may be unsustainable in the longer-term. An example of this is the use of zero tillage without residue retention and without suitable rotations which, under some circumstances, can be more harmful to agro ecosystem productivity and resource quality than a continuation of conventional practices (Sayre, 2000). To date, the most successful resource conserving technology in the rice–wheat systems has been zero-tillage wheat, particularly in the Indian Indo-Gangetic Plains (RWC, 2004). Zero tillage is also known as zero till, no till, direct seeding and direct drilling (Erenstein et al., 2008).

1.4 Reasons for adoption of zero-tillage in wheat

Who are adopters

All categories of farmers

Drivers of adoption

- (a) Cost saving and thus higher profit,
- (b) Saving of irrigation water, especially in first irrigation, and
- (c) Improvement in soil fertility due to decomposing of paddy stubbles in soil.
- (d) Good for late sown conditions. The date of sowing is also advanced for a couple of days.

1.5 Major adoption facilitating factors

- (a) Refinement of zero-till drill
- (b) Promotion of manufacturing of the drill and provision of subsidy by the government
- (c) Integration of research efforts and large-scale demonstrations on farmers fields in a persistent manner

1.6 About the zero tillage technology

Zero-tillage is the direct placement of seed into the soil without any land preparation. In areas where the soils are fine textured, poorly drained and land preparation is difficult, it often results in a cloddy tilth. The seed germinates into the moist soil and the roots follow the saturation fringe as it drains down the soil profile. Moisture level must not be too high as oxygen is needed for healthy root growth (Mehta and Singh, 2002). Use of zero-tillage in wheat was promoted to overcome the problem of resistance of phalaris minor against the herbicides. In zero-tillage system, inter-row space is not disturbed and germination of phalaris minor is comparatively less. Weed management and crop establishment are high priority thrust areas for wheat cultivation. Phalaris minor is an important weed of wheat crop. The germination of phalaris minor depends on two factors: (i) time of sowing of wheat; and (ii) tillage disturbance of soils. Zero till drill not only disturbs the soil least but also advances the sowing of wheat, which is beneficial for wheat crop. Zero-tillage not only reduces the weed population and cost of cultivation but also reduces lodging of the crop. Due to resistance in phalaris minor against popularly used weedicide Isoproturon, the population of this grassy weed increased tremendously. For enhancing the productivity and sustainability of the rice-wheat system without affecting the natural resources, zero-tillage is becoming popular amongst the farmers. The increasing cost of cultivation is continuously making the farming business less profitable as there is a little scope to further increase the yield of wheat to a substantial extent. Only way to increase profitability is by reducing the cost of cultivation. The land preparation after paddy for wheat sowing involves huge

expenditure as 5-6 cultural operations are to be performed for seedbed preparation. In zero tillage, wheat is directly sown without disturbing the soil, which increases yield and lowers the cost by saving fuel, water, herbicides and labour.

The prevailing zero tillage technology in the Indo-Gangetic Plains uses a tractor drawn zero-till-seed drill to seed wheat directly into unplowed fields with a single pass of the tractor. The typical zero tillage drill has inverted-T openers and opens a number (6–13) of narrow slits for placing seed and fertilizers at the depth of 7.5–10 cm into the soil (Mehla et al., 2000). The zero tillage drills are made domestically and cost Rs 16,000–20,000 (around US\$400, Parwez et al., 2004; Thakur, 2005). Surface seeding provides a manual alternative, whereby wheat seeds are broadcast on a saturated soil surface before or after the rice harvest (Hobbs et al., 1997, Tripathi et al., 2006). Surface seeding is a simple technology for resource-poor farmers requiring no land preparation or machinery, but its use is still largely confined to low-lying fields that remain too moist for tractors to enter, particularly in the Eastern Indo-Gangetic Plains. Zero tillage as applied to the rice–wheat systems in the IGP has three distinctive features that distinguish it from related systems elsewhere (e.g. Ekboir, 2002; Erenstein, 2003). First, zero tillage is typically only applied to the wheat crop in the double-cropped system, with the subsequent rice crop still intensively tilled. Second, zero tillage wheat after rice does not necessarily entail an increased reliance on herbicide, reflecting that paddy rice fields are relatively weed free at harvest time. Third, zero tillage wheat does not necessarily imply the retention of crop residues as mulch. In fact, the prevailing Indian zero tillage seed drills are relatively poor in trash handling, but for better or for worse, this was not a major issue in view of the limited biomass remaining in rice–wheat systems after the prevailing rice crop and residue management practices (Timsina and Connor, 2001, Erenstein et al., 2007) environment.

1.7 Major challenges

Starting from the 1960s, expansion of area and growth of rice–wheat productions system based on the adoption of modern technologies, incorporating the use of high-yielding varieties, fertilizers and irrigation, led to increased production

and productivity of both these crops. However, continued intensive use of these technologies in recent years has resulted in lower marginal returns and, in some locations to salinization, overexploitation of groundwater, physical and chemical deterioration of the soil, and pest problems.

There are many approaches to overcome these problems, of which, straw retained on the soil surface reduces weed seed germination and growth, moderates soil temperature and reduces loss of water through evaporation. Despite these potential benefits, however, large quantities of straw (left over after rice and wheat harvesting) are burnt each year by farmers to facilitate land preparation for crop planting. It is estimated that the burning of one ton of straw releases 3 kg particulate matter, 1460 kg CO₂ and 199 kg ash. With the development of new drills, which are able to cut through crop residue, for zero-tillage crop planting, burning of straw can be avoided, which amounts to as much as 10 tons per ha, potentially reducing release of some 13–14 tons of carbon dioxide (Gupta et al., 2004).

1.8 Need of the study

Despite of the fact that resource conservation technologies are proved to be cost reducing, profitable and sustainable on farmers' field and research farms, the demand and diffusion of these technologies are not getting momentum as per the estimation and expectation of the researchers, extension workers and policy makers.

The major challenge to wheat production in the state is the enhancing of its productivity and profitability. Adoption of zero tillage technique is one such step in this direction. As an alternative to the conventional tillage, zero tillage technology uses direct seeding of wheat crop just after harvest of rice with the help of zero-till seed drill without preparatory tillage. Thus, zero-tillage ensures early sowing of wheat and reduces cost of cultivation.

Therefore, the present study entitled “Demand, Diffusion, Economics and Impacts of Resource Conservation Technologies in Eastern Uttar Pradesh”, therefore, undertaken to highlight the various issues and challenges that are being faced in

adoption and spread of selected resource conservation technologies. For the purpose of detailed analysis, one technology which is having more prevalence and coverage i.e. zero tillage has been selected for deciphering the detailed impact and adoption of study area. The present study was proposed to be undertaken with following specific objectives:

1.9 Objectives

1. Elicit and characterize farmer's demand and diffusion for zero till and its forecasting in the rice wheat cropping system.
2. To find out the economics of wheat under RCT
3. To determine the relative importance of the various factors influencing adoption of Resource conservation technology.
4. To assess the economic and environmental impacts of zero tillage

1.10 Plan of study

With the above brief introduction of the research, the brief resume of the important work done by the previous researchers is presented in Chapter II. Chapter III deals with the methodological details for the fulfillment of the objectives of the present study. The description of study area is given in Chapter IV. Chapter V is devoted to results of the present study, which are discussed in detail with the help of table and figures. In the last chapter, the whole work is summarized and concluded followed by bibliography.



REVIEW OF LITERATURE

Review of literature relevant to the study in hand helps to understand the past works in the field and identify gaps in research. Moreover, they also serve as basis to defend findings in line with past finding. In case of differences, explanations need to be produced. In order to evaluate the objective of the study, it is desirable to have an idea of the findings of related studies and the methods adopted for arriving at the same. A brief review of the earlier research work related to the present study is presented in this chapter.

Keeping in view the objectives of the study, the review is presented under the following headings.

- 2.1 Resource conserving technologies
- 2.2 Economic analysis of RCTs
- 2.3 Factors affecting adoption of RCTs
- 2.4 Environmental and economic benefits

2.1 Resource conserving technologies

Sharma (1981) identified the factors significantly influencing adoption of modern varieties by the farmers in Nepal. The factors were land size, education, contact with extension workers, membership of cooperative, and distance to agricultural offices, tenancy case, and state of knowledge of institutional aspects relating to improved wheat farming. It was recommended that the non-formal education, group extension programme, cooperative and dissemination of institutional information to farmers should be promoted.

Harman *et al.* (1985) found that the adoption of a no-till food-grain production system in a crop rotation with irrigated wheat production increases farm income,

reduces underground water depletion, conserves energy, and reduces labor needs. Simultaneous attainment of these items might be considered compatible multiple goals of Great Plains farmers facing rising production costs, a declining water table and narrowing profit margins. Increased profitability of the no-till food grain production system over conventional tillage is due largely to three items: (1) increased yields, (2) reduced fuel and labor requirements of irrigating and tillage, and (3) savings in machinery depreciation costs. Profits can be doubled with no-till in the high lift, rising gas price situation at 5 or 10 per cent discount rates.

Shakya and Flinn (1985) examined the factor affecting the adoption of modern variety of rice and fertilizer in Tarai of South-Eastern Nepal through multivariate probit and tobit regression models. They found that adoption of modern rice technology was higher where there was facility of assured irrigation. Tenure status and access to credit were significantly related to varietal adoption but family, farm size and the farmer's education were not affecting the adoption. Similar variables in addition to fertilizer price influenced the probability of fertilizer adoption in rice.

Adhikari and Patel (1986) investigated the direct and indirect effects of various socio-psychological characteristics of the Nepalese farmers on the utilization pattern of recommended technologies of rice cultivation. It was found that age, education, size of holding, family size, year of experience in farming and availability of irrigation facilities gas little relation to the use of improved paddy cultivation technology.

Ashraf *et al.* (2001) found that resource conservation technique as bed, furrow, zero tillage and conventional methods were evaluated in this study. Wheat was sown by these techniques during the rabi 2000. Soil samples, up to 120 cm depth, at an interval of 15 cm depth were collected before sowing and after harvesting for salinity analysis. Form a skimming well, measured amount of water was applied at fixed moisture depletion level. Farmers existing practices on irrigation was also recorded. The total depth of water applied was 42.47 and 31 cm for bed and furrow, basin and zero tillage fields, respectively. The water use efficiency was 1.22, 1.09 and 1.41 kg

m⁻³ for bed and furrow, basin and zero tillage fields, respectively. The farmer applied 79 cm of water almost double than water applied under the schedule fields, with a WUE of 0.63 kg m⁻³. Soil salinity remained within threshold limit for all the techniques.

Hobbs and Gupta (2001) studied that the resource-conserving technologies described in this paper offer considerable potential for sustainably improving the productivity of wheat in South Asia's rice-wheat systems, raising input use efficiency, cutting costs, providing various environmental benefits and ultimately improving farmer livelihoods, among other things by helping to reduce poverty. The resource-conserving practices described here is zero-tillage and bed planting for wheat address the problems of late wheat planting and poor plant stands that represent serious constraints to wheat yields under conventional tillage. Several pending issues relating to the new practices including interactions between tillage and fertilizer use (methods and timing of application), residue management, and development of improved equipment, pest management strategies, variety, and the interaction with crop establishment practices for rice were also discussed. Farmer response to these technologies has been very favorable and area has risen from a few hectares in 1998 to more than 100,000 in 2001. Continued acceleration of adoption is expected as local manufacturers increase their capacity to meet the demand. The paper lists the many benefits farmers encounter in the new practices. Resource conserving technologies are a key to ensuring sustainable food production in South Asia in the next decade.

Steiner (2002) found that conservation tillage aims at making better use of agricultural resources through the integrated management of available soil, water and biological resources, combined with limited external inputs. It contributes to environmental conservation and to sustainable agricultural production by reducing soil disturbance and protecting the soil with a permanent or semi-permanent organic cover. Adoption of CT at farm level is associated with lower labour and farm-power inputs, more stable yields and improved soil quality. Crop production profitability under CT tends to increase over time in relation to conventional agriculture. Despite these apparent advantages, CT has spread relatively slow with the exception of Latin

America. Transformation from conventional agriculture to CT seems to require considerable farmer management skills and involves investments in new equipment. It may also require some social capital to enhance its dissemination.

Unger (2002) found that improved water (also soil) conservation has been achieved in many cases by using conservation tillage, including no-tillage, which is the ultimate type of conservation tillage. The purpose of this article is to review and discuss the principles and practices of conservation tillage and the results of some studies relative to their effect on conserving water for improving crop yields in dry land regions such as those in southern South America. Water and soil conservation is possible by using tillage methods that reduce the amount and/or rate of runoff and improve water infiltration in soil. This is possible even when crop residues are not retained on the soil surface, which is covered by the broad definition of conservation tillage. Improved water and soil conservation, however, usually occurs when crop residues are retained on the soil surface, as covered by the operational definition of conservation tillage. Water and soil conservation usually improves with increasing amounts of residues retained, and results of numerous studies involving conservation tillage, including no tillage, show that increased water conservation increases the yield of dry land crops. Improved soil conservation resulting from use of conservation tillage helps protect soils for sustained crop productivity.

Pandey *et al.* (2003) found that the parameters such as yield increase, reduction in cost of production and technical and economic efficiency were used to assess the economic benefits. Determinants of technical efficiency in the term of the adoption of zero tillage technology and producer characteristics were also examined impressive cost saving under the zero tillage. The technology had positive and significant impact on environment and sustainability of the system through improved soil quality and reduction in use of inputs and energy.

Sain and Morris (2003) studied the results of the economic profitability analysis and of the water productivity analysis will be used to derive policy recommendations aimed at bringing about more technically, economically, and

socially efficient use of water. Such policy recommendations will necessarily requires a clear understanding of the technical and economic impacts of changing from traditional tillage practices to ZT.

Harrington and Erenstein (2005) observed that with the rapid expansion of wheat zero tillage in the Indo-Gangetic Plains, there has been within that region a surge of interest in resource conserving technologies (RCTs). But other regions of the world have also made progress in fostering farmer use of these practices. This paper defines RCTs and conservation agriculture (CA), and then summarizes a global perspective on CA and RCTs, emphasizing recent advances in selected developing countries, among them China, Central Asia, southern Africa, and the southern Cone of South America. Success in the introduction of CA practices is found to be favored by the following factors: emphasis on development and adaptation of suitable implements often using prototypes from elsewhere; participation of the private sector in implement development, adaptation, manufacture and marketing; long-term technical mentoring; strong local champions; a crisis mentality that brings with it a willingness to consider radical departures from conventional practices; and the emergence of a dynamic innovations system.

Akhtar (2006) attempted the production techniques intervening flooded irrigation method for efficient utilization of resources is being recommended and same has been activity adopted in many countries of South Asia. The resource conservation technologies (RCTs) mainly include bed planting of wheat, sowing of wheat following zero tillage technology, bed and furrow sowing of cotton and management of crop residues. Laser land leveling adopted in Pakistan has shown encouraging results under zero tillage technique wheat was sown using residual moisture with no or minimum tillage without irrigation the field with the aim to sow wheat in time offer rice, conservation of wheat and reduced cultivation cost. Latest dimension of zero tillage and bed planning are also being highlighted in favour of this technology including improving soil biodiversity, reduced air pollution, mitigation of environmental degradation after residue burning and carbon sequestration.

Doss (2006) found that Policy makers and interest groups have many questions about the use of improved technologies in developing country agriculture. These include the roles of policies, institutions, and infrastructure in the adoption of improved technologies and their impact on productivity and welfare. Most micro-level adoption studies, however, cannot address these important policy issues. Drawing on an extensive review of the literature on the adoption of agricultural technologies, this article suggests alternative approaches for designing technology adoption studies to make them useful for policy makers. It explores the generic limitations of cross-sectional adoption studies carried out in small numbers of communities and discusses some problems faced in conducting such studies. Recommendations include the use of sampling approaches that allow data from micro studies to be generalized to higher levels of aggregation, adherence to clearly defined terms that are standardized across studies, and careful examination of the assumptions that often underlie such studies.

Das and Bauer (2008) observed that sustainable resource management was widely acknowledged as important strategy to poverty and environmental degradation in all the developing countries. Management of soil organic matter in a way that it supports current as well as future long term food production is the principle for sustainable agricultural practices. Resource conserving technologies for zero tillage, mulch tillage and minimum tillage were in the link with this principle and shown better performance in most of world. Therefore, the study attempts to perform economic analysis of minimum tillage as a feasible resource conservation technology in a typical mid farming system of Nepal. The result of the cost benefit analysis for next five years of time horizon show that minimum tillage could be a financially attractive technology for maize cultivation in rain fed lands of the hill region. Since, minimum tillage is able to conserve a substantial amount of soil and nutrient, it has long term positive impact on the crop yield in comparison to the conventional tillage system.

Fuglie *et al.* (2008) studied that a national sample of US farmer is used to estimate the long term trends in adoption and diffusion sample of conservation tillage, IPM and soil fertilizer testing, and technologies designed to reduce environmental

externalities from agriculture. Results from a duration model show that diffuse of these technologies have been relatively, farm size, farmer education and regional factors. Growing awareness and concern about the environmental costs of agriculture production have given a new technology impetus to increasing the use of farm practices that reduce production externalities. In crop agriculture, conservation tillage, IPM, soil nutrient testing and more recently, precision agriculture, are examples of technologies that are being promoted to help conserve natural resources by reducing soil erosion and excessive application of chemicals and fertilizer.

Maheswari *et al.* (2008) found that the study conducted in the Dharmapuri district, has collected data on the precision and non-precision framings through the interview schedule during the year 2007. Source of the productivity differences between the precision and conventional farming have been identified by decomposing the productivity change. Financial impact of adoption has been studied through a two-stage economic model. The first of the model consist of an adoption decision model that describes the factors which influence the likelihood of adoption precision farming. Results model that stage have provide input for the second stage of the adoption of the model, which has been revealed that adoption of precision farming has led to 80 per cent in yield in tomato and 34 per cent in brinjal production. Increase in gross margin has been found as 165 and 67 per cent, respectively in tomato and brinjal farming. The contribution of technology for higher yield in precision farming has been 33.71 per cent and 20.48 per cent, respectively in tomato and brinjal production. The elasticity of production of 0.39 for the adoption in tomato and 0.28 in brinjal has indicated that as the probability of adoption increases by 10 per cent, net return increases by 39 per cent and 28 per cent in tomato and brinjal cultivation. Lack of finance and credit facilities have been identified as the major constraints in non-adoption of precision farming.

Pala *et al.* (2008) found that with increasing land use pressure in semi-arid dry Middle Eastern agriculture, fallow based cereals production has given way to cropping intensification, including legume based rotation along with conservation tillage and on farm straw disposal. Such agronomic developments can only be

biologically and economically assessed in multiyear trails. Thus this ten year study examined the influence of tillage system (conservational and fallow) and variable stubble management, including compost application, on yield of barley and retch grown in soil incorporating the straw and stubble. Barley, straw and grain yield were generally higher with the mould plough. Similarly with vetch treatments involving compost application yielded significantly higher than burning incorporating the straw and stubble. Despite yearly difference between crop yields, the pattern of treatment difference was consistent. Thus, the cereal-vetch rotation system is sustainable, while excess straw could be used as compost with benefits to the crop. Though there was no clear advantages to the shallow conservation type tillage, the energy cost are less, thus indicating its possible advantage over conventional deep tillage in such rotational cropping system.

Shanwal and Lohan (2008) examined that the various technologies developed and adopted for soil resources conservation in Siwaliks of Haryana under IWDP (Hills-1) program on watershed basis. The technology which included the harvesting and engineering aspect and alternative land use system on agronomic aspect was adopted in two different watersheds representing the agro-ecological zones. The results of various technologies adopted for watershed development showed that good number of small capacity WHS's were more successful in comparison to few WHS's of large capacity.

Sullivan *et al.* (2008) examined that conservation tillage is a commonly adopted best management practice for improving soil quality and reducing erosion. However, there are currently no methods in place to monitor conservation tillage adoption at the watershed scale. The primary objective of the study was to evaluate the usefulness of land sat TM data as a tool to depict conservation tillage in a small coastal plain watershed. Satellite imagery was used to calculate four commonly used indices: Normalized Difference Vegetation Index, crop Residue Cover Index and the simple tillage Index. A logistical regression approach was used on two subsets of the data set ($n = 20$ or $n = 44$) to determine the influence of the number of ground control points on the success of modeling the occurrence of conservation tillage. The most

accurate model was re-applied to the satellite image and evaluated using an independent sample of 94 survey sites. Results indicate that the normalized difference tillage as simple tillage indicate performance best, with an overall accuracy of 71 per cent and 78 per cent for models developed using $n = 20$ and $n = 44$ sample locations, respectively. Errors were typically in the form of commission. Results are encouraging and suggest that currently available satellite imagery can be used for rapid assessment of conservation tillage adoption using minimal a priori information.

Twomlow *et al.* (2008) found that good management of natural resources was the key to good agriculture. This is true everywhere and particularly in the semi-arid tropics, where over exploitation of fragile or inherently vulnerable agro ecosystems is leading to land and soil degradation, productivity decline, and increasing hunger and poverty. Modern crop varieties offer high yields, but the larger share of this potential yield can only be realized with good crop management. The International Crops Research Institute for Semi-Arid Tropics (ICRISAT) working over a vast and diverse mandate area, has learned one key lesson that technology and interventions must be matched not only to be the crop or livestock enterprise and the biophysical environment, but also with the market and investment environment, including input supply system and policy.

Erenstein (2009) found that the success of zero tillage wheat in the rice system of indo-gangetic plains. Diffusion of the zero-tillage technology increased in the last decade, particularly in northwest India. In 2008, in India alone, the aggregate area in zero- or reduced –tillage wheat amounted to 1.76 million hectares, and it was used by 620,000 farmers. Zero-tillage wheat allowed for a drastic reduction in tillage intensity, resulting in significant cost savings as well as potential gain in wheat yield through earlier planting of wheat. Wheat farmers who adopted zero tillage could enhance their farm income by about US\$100 per hectare. The cost-saving effect alone makes zero tillage profitable and is the main driver behind its spread. The potential environment benefits of zero tillage have yet to be fully realized and imply tackling the challenge of reducing tillage for the rice crop that follows wheat, retaining crop residues as mulch, and diversification of crops.

Subbulakshmi *et al.* (2009) observed that the conservation tillage decreases soil erosion, leaching of fertilizer, pesticides and herbicides into the ground water. Conservation and conventional tillage greatly affected bulk density and flora. Some studies showed that soil microbial activity was higher with conventional tillage due to better aeration. Numerous studies conducted in temperate climate zones showed that no tillage resulted in acidification of surface layer when continued for several years compared to conventional tillage. Conservation tillage increases soil infiltration rate and reduce soil evaporation there by it increases soil water storage, while other studies stated that soil crusting at a slower rate on no-till surface than on the tilled reducing the infiltration carbon content, while other work reported a decrease in soil organic matter compared to ploughed soil down to a depth of 10 cm after 3 years of study. Zero tillage gives smothering effect to weeds but some studies shows that, higher density of grass weeds in crops grown under the Zero tillage have yielded as similar as or better than those grown under conventional tillage, while some workers revealed conventional tillage increased the yield of crops and other scientist reported there no yield difference between any tillage system.

CIMMYT (2010) observed that Zero-tillage cultivation is a farming practice that reduces costs while maintaining harvests and protecting the environment. During 1997-2004, an estimated 620,000 farmers in northern India adopted the method to sow wheat after the rice harvest on around 1.76 million hectares of land, with average incomes increasing by US\$180-\$340 per household per year. The impact achieved resulted from long-term efforts involving direct promotion and testing with farmers, training and support for national programme champions willing to oppose conventional wisdom about tillage practices and development of affordable, locally-manufactured seed drills. Efforts were led by the Rice-Wheat Consortium (RWC) for the Indo-Gangetic Plains, a partnership involving the national research programmes of Bangladesh, India, Nepal, and Pakistan, and with key technical and logistical support from the International Maize and Wheat Improvement Center (CIMMYT).

Ghosh *et al.* (2010) conducted a study on conservation tillage in the terrace up land, valley upland and lowland situations revealed that with appropriate resource

conserving techniques, particularly zero/minimum tillage with residue retention, it was possible to use the rice fallow to raise a second crop of wheat, linseed and mustard in lowland, field pea in valley upland and mustard in terraced upland situations. This will improve the farmer's income, put in use on-farm resources and ultimately ensure food security in marginal areas in the hilly ecosystem. Zero-tillage with residue retention not only favorably moderated the soil rhizosphere and produced higher grain yield in long-term perspective, but also made water available for crops during dry periods by permitting downward movement of water across the root boundary.

Kaur *et al.* (2012) assessed the impact of laser leveling from the data collected from 25 farmers Kokri Kalan village of Moga district, Punjab. It was found that laser leveling farmers could save irrigation water and energy by 24 per cent and obtained 4.25 per cent higher yields. The irrigation cost reduced by 44 per cent over the conventional practice, and water productivity improved by 39 per cent. The returns over variable cost were higher by Rs. 1000 per ha with application of this technology. It was suggested that laser land leveling had a great potential for optimizing the water-use efficiency in paddy cultivation without any disturbing and harmful effect on its productivity.

Kumar and Palanisami (2010) found that the adoption of drip irrigation technology has increased the net sown area, net irrigated area and thereby has helped in achieving higher cropping intensity and irrigation intensity. It has been found that there is a significant shift towards crops such as coconut, grapes and banana from annual crops like vegetables, sugarcane and the like. The main reasons have been found as scarcity of human labour and water. As the cropping pattern decides the adoption and suitability of drip irrigation, widespread adoption of micro irrigation could be promoted in the regions where shift toward crops like coconut, banana and grapes are common. The analysis of economics of crop cultivation under drip and control has revealed that the drip method of irrigation has a significant impact on resource saving, cost of cultivation, yield of crops and farm profitability. The physical

water and energy productivity is significantly high in drip over the flood method of irrigation.

Mike LeBeau (2011) observed that the conservation of resources (land, water, energy) saves cost of water, energy and protects environment while leading to improved productivity on sustainable basis. Targeting the resource conserving technologies offers newer opportunities of better livelihood for the resource poor small and marginal farmers. The major areas of research under this theme cover water conservation, planting techniques such as raised bed and bed furrow planting; orchard floor management, mitigation of desertification and case studies on resource economics.

2.2 Economic Analysis of RCTs

Iqbal *et al.* (2002) observed that in Punjab such an assessment was required not only to understand the current status of technology but was also needed to provide feedback from farmers' field regarding its impact on wheat yield and farm incomes. The wheat acreage sown with zero-tillage technology is expected to expand rapidly in the rice-wheat zone. The study confirms that the zero-tillage technology enhances water and fertilizer use efficiency. However, sufficient evidence was not available to prove any positive or adverse effect of the technology on incidence of weeds in wheat crop. The new technology reduces costs of production with comparable wheat yields to that obtained using other methods and thus results in higher net farm returns. The farmers of the area have started appreciating the reduced tillage cost aspect of the technology however they were not much convinced about the enhanced yields and increased input use efficiency of water and fertilizer. The proper promotion of these aspects of the technology would accelerate adoption and result in increased demand for the drills.

Luhach (2004) examined the water-use efficiency and economic worth of investment in sprinkle, drip and surface irrigation systems in Haryana using the primary data. The results have indicated considerable savings in water from sprinkle

and drip irrigation methods. The sprinkle irrigation method has also been found to reduce operational costs as well as labour requirements. Using different project evaluation criteria, it has been suggested that it is worth to invest into the sprinkle and drip irrigation systems.

Tripathi (2006) examined that the study has shown the economic superiority of the zero tillage over the traditional method of wheat production. The zero tillage has shown tremendous potential for improving soil quality and sustainable its fertility by increasing carbon sequestration and decreasing net emissions of carbon dioxide. Organic matter depletion can be slowed and reversed through reductions in tillage operation. The average operational cost of Rs. 15275 per ha under traditional method has been reduced by about 14 per cent in zero tillage (Rs.13146 per hectare). The costs on machine labour and irrigation have been reduced by about 29 per cent and 18 per cent in zero tillage as compared to those on conventional method, respectively. The net income of Rs 17942/ha on operational cost for wheat production in zero tillage is significantly higher than that of Rs. 15525/ha on earned by the conventional method. Benefit-cost ratio has depicted the zero tillage to be economically more feasible and attractive option (2.36) than that the conventional method (2.02).The positive and significant regression coefficient of zero tillage has explained clearly that this technology had preparation and irrigation factors have revealed that these variable have strong negative influence in net return if wheat under zero tillage method. Thus, the zero tillage is capable to improve the quality of soil, people and eventually reduces social poverty. The study has suggested promotion of zero tillage technology by encouraging private entrepreneurship in production of specific implements required for this technology.

Rama Rao *et al.* (2010) found that the economic return to investment made in soil and water conservation research have been analyzed. Technologies such as conservation furrow, residue incorporation have been found to be economically viable under farmer's conditions. The study has covered four locations, viz. Agra and Varanasi in utter Pradesh, Kota in Rajasthan and Jabalpur in Madhya Pradesh. The economic surplus analysis has revealed that when adopted on a large scale, soil and

water conservation technologies generate significant economic surplus as reflected in high NPV and BC ratio. The share of producer surplus has been found to be higher in the total economic surplus generated from technology adoption. Thus, investment in generation and transfer of soil and water conservation technologies have been found to be justified in terms of economic benefits. However, various constraints that hamper adoption of these technologies are to be addressed so that the potential benefits could be realized by both farmer and consumer.

2.3 Factors affecting adoption of RCTs

Baylin and Pahunang (1980) conducted a study to find out the factors affecting the adoption of farming technology among corn farmer in Bukidnon. The sample were classified the 75 farmers in to modern, traditional mixed farmers. The chi-square test showed that farmer's educational attachment and ethnic origin as well as the distance of their farm to market outlet, especially to National Grain Authority (NGA) warehouses, were closely associated with their decision to adopt modern farming technology. The size of farmer's capital investment was associated with their adoption of modern technology for the wet season only.

Rawal (1981) examined the factor affecting the proportion of farmers land planed to modern varieties of rice and wheat in eastern Nepal. Using multiple regression analysis, he found that the farmers educational status; their exposure to extension and experience were the significant factors influencing the decision of adoption of modern varieties

Bajaj and Kamble (1982) interviewed the tribal farmers in the Akola Tribal department block of Ahmednagar District of Maharashtra to determine the way in which the social value affected the adoption of agriculture innovation. An adoption index was constructed based on the total number of year in which the farmers has adopted the improved practices comprising the use of improved varieties, pesticides, and modern seed rates. It was found that the tribal farmers were conservative and less likely to adopt the new innovation.

Dinampo (1983) identified the factors associated with the adoption of new rice technology in Philippines. The result indicated that the farmers socio-economic statuses; viz. land tenure, size of farm, crop income, their exposure to farming information and involvement in the farmers' association were significantly associated to the adoption of technology. Also the farmers perception about the nature of innovations and there rate of adoption were significantly related.

Kalineza *et al.* (1999) studied the factors that influence smallholder farmers' decision to adopt soil conservation practices using descriptive statistics and logistic regression model. Data for the study were collected from 114 randomly selected households from four villages in Gairo division. The results of descriptive analysis suggested that technology related factors such as labour requirement and perceived technology benefits influence the adoption of soil conservation practices. Results of the logistic analysis revealed that farmers who obtained knowledge on soil conservation through extension/training seminars as well as those with secure land ownership were likely to adopt soil conservation technologies.

Tadesse and Belay (2004) identified important factors, which influence adoption of physical soil conservation measures in the Southern Highlands of Ethiopia, Gununo area. Data collected from a random sample of 120 heads of households were used to estimate the binomial logit model. The empirical results showed that the major factors influencing adoption of physical soil conservation measures in the study area were: farmers' perception of soil erosion problem; technology attributes; the number of economically active family members; farm size; family size; wealth status of the farmer; and the location of the farmland. It was suggested that any intervention in soil conservation should recognize the heterogeneity in household characteristics, land holding, institutional patterns and technology specific traits.

Baradi (2005) surveyed 135 participants from four different locations in the state of Kansas between August 2006 and January 2007. The adoption process was modeled as a two-step econometric models consisting of farmers' perception and

adoption equations to estimate the impacts of demographic variables and farmers' familiarity with and participation in certain conservation programs. Logit model was used to identify the factors responsible for adoption of conservation tillage. Net return was found statistically significant between no-till and other tillage systems variable and the perception variables was not statistically significant. Result revealed that the adoption was motivated by farmer's perception that the technology was profitable and not by their perceptions of environmental policies. Similarly, familiarity and participation were statistically significant indicated that awareness and knowledge of the technologies through familiarity with and participation in conservation programs motivated the farmer's to adopt modern technologies.

D'Emden *et al.* (2006) used 900 farm households dataset for the study based on a farm household survey conducted in Ethiopia during October to December 2010 by the Ethiopian Institute of Agricultural Research (EIAR) in collaboration with the Inter-national Maize and Wheat Improvement Center (CIMMYT). The multinomial logit selection model results revealed that the likelihood of adoption of a package of Sustainable Agricultural Practices (SAPs) was influenced by observable plot, household and village characteristics. These included rainfall and plot level disturbances; soil characteristics and distance of the plot from home; social capital in the form of access and participation in rural institutions; the number of relatives and traders known by the farmer; market access; wealth, age, spouse education and family size; the farmer's expectations of government support in case of crop failure; and confidence in the skill of public extension agents. The significant role of social capital suggested the need for establishing and strengthening local institutions and service providers to accelerate and support adoption of SAPs. The effects of weather related risks were also found important for enhancing SAP adoption and underscore the need to provide climatic information, not only in terms of rainfall amount but also its timing and distribution. Furthermore, the use of SAPs was found positively associated with the farmer's expectation of timely government support during crop failure and with confidence in the skill of extension agents.

Erenstein *et al.* (2007) conducted a study in Haryana, India and Punjab, Pakistan to analyze the adoption of zero tillage (ZT) by using binomial logistic model. The results revealed that the ZT was primarily adopted by the large and progressive farmers in both Haryana and Punjab.. The structural differences between the adopters and non-adopters in terms of resource base, crop management and performance thereby easily confound the assessment of ZT impact across adoption categories. Findings confirmed significant ZT-induced resource-saving effects on farmers' fields in terms of diesel and tractor use under wheat cultivation in both, Haryana and Punjab. Water savings were however less pronounced than expected from on-farm trial data. It was only in Haryana that there were significant ZT-induced water savings in addition to significant yield enhancement. The higher yield and water savings in Haryana resulted in significantly higher water productivity indicators for ZT wheat. In both sites, there were limited implications for the overall wheat crop management, the subsequent rice crop and the rice-wheat system as a whole. The ZT-induced yield enhancement and cost savings provided the much needed boost to the returns to, and competitiveness of wheat cultivation in Haryana. In Punjab, ZT was reported as a primarily cost-saving technology.

Laxami and Mishra (2007) examined the study the economic benefits of zero tillage farming, using primary data from Hararyana and Bihar. The results show that ZT saves diesel and reduces cost of cultivation. Its increases yield of wheat in both states, although the increase in yield is statistically significant in Bihar only. Further, the adoption of ZT may be successfully implemented through timely availability of ZT machines, developing market for hired services and proper administration. The results also indicate that the probability of adoption is the higher for the experienced but relatively young farmers. The govt. policies to improve human capital in the form of training and awareness are beneficial for the adoption of ZT. Thus there is a need to have resource allocation to improve the human capital through extension programmes, village community meeting, farmer fairs, etc., for enhancing of adoption. The availability of credit play a very important role in this decision making process.

Sarwar and Goheer (2007) found in a study that the major cropping systems of South Asia is rice-wheat, grown on 13.5 million hectares on the Indo-Gangetic Plains (IGP). It has a pivotal role in the food security and livelihoods of millions of farmers and workers. Continuously, need is being felt to explore the possibilities of saving critical inputs by adopting alternative resource conservative technologies as zero tillage. Main aim of this paper was to see factors affecting the adoption and impact of zero tillage technology in rice wheat system. Economic analysis of the data presented in this paper shows that zero tillage method for wheat cultivation is the most economical and attractive option for farming community. The high yield grain and less cost of production per ha were noted on zero tillage farms as compared with conventional farms. In this paper, analytical technique was employed for the adoption of zero tillage technology in Pakistan (Punjab). A binary Logit model was also estimated based on the available data set, with the probability of adoption of zero tillage technology as a dependent variable and set of other variables as the explanatory variables. It was found that with the increase in farm size, the probability of adoption of zero tillage technology increases. While with the high NPK nutrients cost per ha and with more tube-well irrigation time required to irrigate one ha of land the probability of adoption of zero tillage technology reduces. Finally, the adoption of zero tillage technology improves farmer's profit and eventually contributes towards reducing poverty and keeping environment clean. However, the long-term impacts of this technology on food production, natural resources (land and water) and linkages with poverty alleviation should be further explored.

Adeogun *et al.* (2008) studied the parameters of the adoption process of Hybrid Clarias Heteroclarias by fish farmers in Lagos State, Nigeria. In this study, a conceptual framework was developed for the decision to adopt or not to adopt and econometric analyses of the diffusion process was presented using Logistic regression model. This paper showed that education, contact with extension agents, access to seed and market distance are significant variables that influence fish farmers' hybrid catfish adoption and use decisions.

Kumar *et al.* (2010) examined the determinants influencing the acceptance of resource conservation technology and identified different factors affecting its adoption using primary data from Uttar Pradesh, Haryana and Bihar. The maximum likelihood estimates of the logit model were used to indicate the factors affecting the adoption of zero-tillage. The results showed that age of the farmers had negative and significant impact on the probability of technology adoption in these states. The effect of education index was negative and significant in the case of Uttar Pradesh and Bihar. The farming experience was found to have positive and significant impact on the probability of adoption in three states. Participation in village community meetings and farmers fair had a significant impact towards the zero-tillage technology in Haryana but the impact was insignificant in Uttar Pradesh and Bihar.

Mojo *et al.* (2010) examined the status and determinants of adoption/diffusion of sustainable land use and crop management technologies, including conservation tillage (CT), crop rotation (CR), fallowing (FL), crop residue management (RM) and organic farming (OF), and compared them with the determinants of adoption of a new crop variety (VT). Data were collected from 297 rural households in Ethiopia from December 2009 to January 2010. A binary logit model was used to analyze the effect of socioeconomic, geographical and social network variables. The empirical results showed that richer households were more likely to use more of these technologies. Focusing on OF as a typical resource conserving technology, it was found that perceptions about the changes in water quantity, household asset, literacy rate, distance to agricultural cooperative, perception about the benefit of the technology, and the density of social networks had a positive impact on the adoption of OF. However, these factors had no significant effect on the adoption of VT. The result also addressed the difference between adoption of resource conserving technologies and standard new technologies such as new varieties.

Singh *et al.* (2011) observed that this study has evaluated the superiority of resource conservation technologies (RCTs) over conventional methods of cultivation and has identified the factors influencing adoption of these technologies. It has provided succinct evidences from four states — Bihar, Haryana, Punjab and Uttar

Pradesh — by comparing the adopters and non-adopters of RCTs in the rice-wheat cropping system of the Indo-Gangetic Plains of India. The study has highlighted superiority of RCTs over the conventional practices in terms of cost saving and efficient inputs-use. However, there is a need to internalize the RCTs in their totality by applying plans and strategies based on local dynamics. The study has suggested the need of policy formulations for dissemination and wider adoption of these technologies.

Ayuya *et al.* (2012) conducted study of small-scale organic maize farmers in Bungoma County. A simple random sampling approach was used to select a sample of 150 smallholder maize farmers and primary data was collected using a semi-structured questionnaire. The Multinomial Logit (MNL) model was used to analyse the factors influencing choice of Organic Soil Management Practices (OSMP) among maize farmers. The results indicated that extension, farm size household size, gender, age, education, credit, group membership, land tenure, farm distance and slope of land significantly influenced the choice of different techniques.

Bakhsh *et al.* (2012) conducted study at the Institute of Agricultural and Resource Economics, University of Agriculture, Faisalabad, Pakistan during the year 2009 with an objective to identify the factors which affect the adoption of water saving practices focusing on cotton crop. Data was collected from 105 cotton growers of two districts of Punjab province i.e. Rahim Yar Khan and Mianwali. The results indicated that adopters of water conservation practices such as ridge/bed sowing had smaller land holdings (27 acres) compared to non-adopters (48 acres). Similarly, land fragments were relatively small for adopters (1.83 fragments) compared to non-adopters (2.67 fragments). Adopters applied higher number of irrigations (7.08) to cotton crop than non-adopters (4.72). The results of Logit model indicated that ownership status, land fragmentation, farming experience, farm assets especially sheep and female workers were significantly related with adoption of water conservation technologies in cotton production.

Grazhdani (2013) examined the impact of socio-economic factors on the adoption of resource conserving technologies on farm of LA-Prespa (Balkan Peninsula). Using the survey data, a logit model was estimated employing the procedure of maximum likelihood to determine the characteristics associated with adoption of environmentally focused technologies. It was found that government financial assistance to farmers, the level farmer education, farmers' income, and farm size had a significant positive effect on the marginal probability of technology adoption. On the other hand, tenure insecurity and age of farmer has significant negative effects on the adoption. Availability of credit to farmers, off-farm employment opportunities, and perception of the resource degradation problem had a positive influence on the probability of adoption, however, their magnitude was not found to be statistically significant.

Ng'ombe *et al.* (2014) identified the major factors affecting adoption of conservation farming (CF) by smallholder farm households in Zambia. This study used data from a nationally representative survey of households in Zambia conducted in 2008. A total sample of 7,825 smallholder farm households was selected using a stratified three-stage sampling procedure. Propensity Score Matching (PSM) was employed to help match the adopters and non-adopters of CF based on the distribution of their similar observable characteristics upon which a separate logistic model was applied. The results revealed that household size; age of household head; marital status; labour availability; distance to access of vehicular roads; location in agro-ecological regions (AER) I, AER II; in-kind income and off-farm income significantly affect adoption of CF. Household size was found to negatively affect adoption of CF but was observed to have a positive marginal increase on the likelihood for farm households to adopt as the household increases in size. Age of the household head had a positive but negative marginal effect on the decision to adopt CF. It was also found that the smallholding farmers in their youthful stage of lives would be versatile to adopting new technologies but it reaches a point in life when they would desist from adopting new technologies. Married household heads were more likely to affect

adoption of CF than single household heads. Labour availability in the farm household was found to positively affect adoption of the technology.

2.4 Environmental and economic benefits

CASA (2004) conducted conference on conserving resources and enhancing productivity of Conservation Agriculture (CA) and evaluated the benefits of conservation agriculture. The cost of wheat production is reduced by Rs.1500 to Rs. 2000 per hectare. Research indicated reduced incidence of Phalaris minor, a major weed in wheat, when zero-tillage is adopted resulting in reduced use of weedicides. Farmers experience indicated that considerable saving in water (up to 20-30 per cent) and nutrients are achieved with zero-till planting and particularly in laser levelled and bed planted crop. In properly managed zero-till planted wheat yields were invariably higher by 4 to 6 per cent compared to traditionally prepared fields for comparable planting date. CA involving zero-till and surface managed crop residue systems was an excellent opportunity to eliminate burning of crop residues which contribute to large amount of green house gases like CO₂, CO, NO₂, SO₂ and large amount of particulate matter. Burning of crop residues, also contributes to considerable loss of plant nutrients, which could be recycled when properly managed. Large scale burning of crop residues is also a serious health hazard. No tillage when combined with surface managed crop residues sets in the processes whereby slow decomposition of residues resulted in soil structural improvement and increased recycling and availability of plant nutrients. Surface residues acting as mulch, moderate soil temperatures, reduce evaporation, improve biological activity and provided more favourable environment for root growth.

Kumar *et al.* (2010) examined the determinants influencing the acceptance of resource conservation technology and identified the socio-economic benefits of zero-tillage farming using primary data from Uttar Pradesh, Haryana and Bihar. The on-farm economic benefits of the adoption of zero tillage were a significant saving in diesel used for preparation of the land and also tractor used for tillage. Increase in

yield was deserved through statistically significant yield gain was observed in Bihar only.

Pal *et al.* (2010) studied the environmental impact of resource conservation technology: the case of zero-tillage in the rice-wheat system of South Asia. There was a saving of 440 m³/ha water in intensively irrigated state of Haryana and 202 m³/ha in Bihar during the entire crop season. It was estimated that saving of diesel reduces CO₂ emission from 84.5 kg/ha under Conservation Tillage (CT) to 21.6 kg/ha under Zero Tillage (ZT) in Haryana. The reduction in CO₂ in Bihar is comparatively low but significant (52.4 kg/ha). Per tonn cost advantage of six per cent was observed, which applied to the wheat production in north-west Indian Industrial General Products (IGP) resulted annual gross benefit of 142 million dollars and a rate of return of 49 per cent on entire Research and Development investment.

IARI (2012) studied the impact of crop residues on soil health and crop yield and impact of crop residues on pests. Study revealed that incorporation of crop residues into soil or retention on the surface had several positive influences on physical, chemical and biological properties of soil. The crop residues act as a reservoir for plant nutrients, prevent leaching of nutrients, increase cation exchange capacity (CEC), provide congenial environment for biological N₂ fixation, increase microbial biomass and enhance activities of enzymes such as dehydrogenase and alkaline phosphatase. Incorporation of crop residues in conservation agriculture had direct and indirect effects on pests.

Kaur *et al.* (2012) conducted study on Resource Conservation Technology in Punjab Agriculture. Data were collected from the village Kokri Kalan in the Moga district. A list of farmers, who have got their fields levelled with traditional method and with laser technology was taken from the co-operative society of Kokri Kalan. A sample of 25 farmers, taken at random, was chosen in such a way that all the farmers fall under the category of partial adopters. Farmers applied laser technology to a part of the cropped area and rest was put under traditional method of cultivation. The results showed that with laser leveling farmers could save irrigation water and energy

by 24 per cent and obtained 4.25 per cent higher yields. The irrigation cost reduced by 44 per cent over the conventional practice, and water productivity improved by 39 per cent. The returns over variable cost were higher by Rs. 1000 per ha with application of this technology. Laser land leveling had a great potential for optimizing the water-use efficiency in paddy cultivation without any disturbing and harmful effect on its productivity.

Meena and Singh (2013) studied the innovations, constraints and strategies for adoption of conservation agriculture. Several benefits of conservation agriculture identified by them which were as follows good plant growth, saving in tillage operation, saving of irrigation water, saving of time and labor, good seed germination and less incidences of weeds, less seed required, less attack of insect pest and proper placement of seeds and fertilizer in lines.

Singh and Meena (2013) conducted study on economics of conservation agriculture and pointed out the on-farm benefits and off-farm benefits of conservation agriculture. On-farm benefits included marked and rapid increase of organic matter content in upper layers of soil and increased biodiversity, number and activity (of earthworms, fungi, bacteria, etc.) in soil, better soil structure and stability of soil aggregates; significantly higher infiltration rates; soil loss reduced by over 80 per cent, runoff by 50 per cent or more, increase in nutrients stored, greater availability of P, K, Ca, Mg in root zone; less fertilizer needed for same result, better germination and development of plants, better root development, yields often higher, typically + 20 per cent for maize, + 37 per cent for beans, + 27 per cent for soybean, + 26 per cent for onions; with less year-to-year yield variation, reduced variations of soil temperature during day, with positive effects on plants' absorption of water and nutrients, less investment and reduced use of machinery and animals in crop production; reduced costs for labor, fuel and machinery-hours perceptible within 2 years, operational net margins per ha rose by between + 58 per cent to + 164 per cent. Off-farm benefits included flooding risks reduced by 30-60 per cent due to greater rainfall infiltration and delays to overland flows, less herbicide used after first years; less pesticide used, more recycling of animal wastes; reduction of pollution and

eutrophication of surface waters by agricultural chemicals carried in surface runoff and eroded soil; less sedimentation and infrastructure damage, e.g. silting of waterways, large dams, reduced water treatment costs due to less sediment, less bacterial and chemical contamination, savings of up to 50 per cent in costs of maintenance and erosion avoidance on rural roads, reductions in fuel consumption of 50-70 per cent or more and proportional reduction in greenhouse gas emissions, reduced pressure on agricultural frontier and reduced deforestation by high-yielding, sustainable conservation agriculture and increased pasture carrying capacity through rotation with annual crops, enhanced diversity and activity of soil biota, reduced carbon emissions through less fuel use and enhanced carbon sequestration by not destroying crop residues and increasing, rather than losing, soil organic matter.

Ahmad *et al.* (2014) identified the constraints of resource conservation technologies in Pakistan. Primary data for this study were collected through two independent but related farmer surveys, conducted by the International Water Management Institute (IWMI), in the Rechna Doab of Pakistan's rice-wheat zone. The first survey was conducted in early 2004, which was based on randomly selected 360 farmers from a stratified sample of villages within the 28 irrigation sub-districts of the Rechna Doab. It was reported that the general constraints to adoption of both zero tillage and laser land leveling were limited access to the zero tillage drill and the laser land leveler, high costs of rental services and financial constraints. Further reasons for non-adoption related to zero tillage were the risk of yield reduction, lack of knowledge and experience on irrigation and agronomic practices, and non-suitability to local conditions (e.g. soil types and crop rotation). The identified constraints were also found to be responsible for coming back to traditional practices.



RESEARCH METHODOLOGY

This chapter is devoted to the methodological details for the fulfillment of the objectives of the study and is divided into three sections. The first section deals with the sampling design used to select the villages and the farmers. The second section deals with the sources and collection of data (primary as well as secondary) while the third section deals with analytical framework applied to attain the objectives of the study:

3.1 Sampling design

3.1.1 Selection of the study area

Multistage stratified purposive sampling was used. There are 75 districts in Uttar Pradesh spread over in four economic zones viz: Eastern, Western, Central and Bundelkhand. All 27 districts of Eastern Uttar Pradesh were arranged according to the adoption level of RCT and Chandauli district having highest adoption was selected purposively. Twenty per cent of total nine blocks were selected (2 blocks) purposively having highest adoption level of zero till. Two villages having highest adoption level were selected purposively from each selected block. Category wise list of farmers was prepared and ten per cent farmers from each category were selected randomly, which finally constituted 52 adopters and 48 non-adopters.

3.1.2 Sampling size: 100 farmer

3.1.3 Selection of RCT

There are different resource conservation technologies like zero till, laser leveler, rotavator etc. Out of them zero till was the only resource conservation technology which was adopted by majority of the farmers of Chandauli, therefore, only zero till was considered for study.

3.1.4 Selection of the respondent

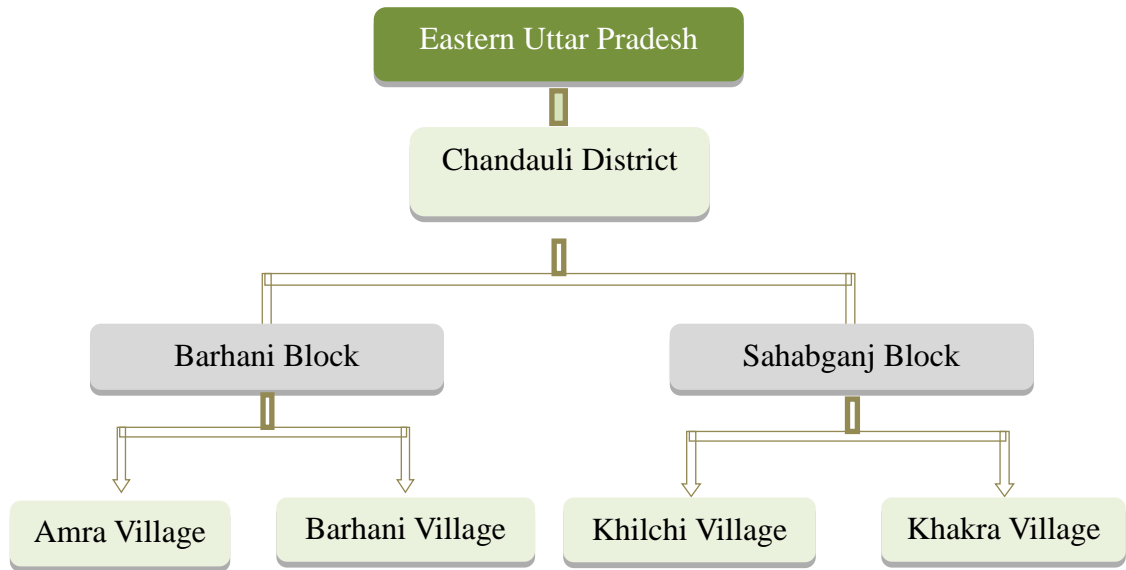


Table 3.1: Category wise selection of the respondents from different villages

Category	Amra Village		Barhani Village		Khilchi Village		Khakra Village	
	Adopter	Non-Adopter	Adopter	Non-Adopter	Adopter	Non-Adopter	Adopter	Non-Adopter
Marginal and Small	7	6	6	6	6	6	6	6
Medium	5	5	6	5	5	5	6	5
Large	1	1	1	1	2	1	1	1
Total	25		25		25		25	

Table 3.2: Distribution of sample

Category	Adopters	Non-adopters
Marginal and Small	25	24
Medium	22	20
Large	5	4
Total	52	48
Total sample size	100	

3.2 Sources and period of data

The primary data was collected with help of pretested schedule by personal interview method for the crop year 2013-14. During the course of investigation, several visits were made for the collection of the required information and the convenience of the farmers was given consideration. Every possible care was taken to ensure the accuracy and reliability of the data. The information provided by the respondents properly edited through cross check. The primary data included various inputs used for crop production in terms of quantity and value, crop output (main and by-products), farm harvest prices of crop grown by sample farmers. The prices of inputs and outputs were collected along with the physical input, output data from the respondents. The wage for human labour and machine labour, the cost of seeds, fertilizers and manure, irrigation and insecticides etc. have been computed at the prevailing rate in the study area. Actual price received by the farmers for their produce was considered for the analysis. Secondary information was collected from published journal, bulletin and official records of districts and blocks.

3.3 Analytical tools

The following analytical framework was used for empirical analysis in order to achieve different objectives of the study.

3.3.1 Descriptive statistics

Descriptive statistics such as percentages, mean, and averages were used to analyze the socio economic characteristics of the adopters and non-adopters of the RCT's like age, household size, sex, education level, total farm size, total area devoted for crop production.

3.3.2 Analytical tools used to achieve the first objective

3.3.2 (a) To assess the demand of the RCT, willingness to pay method was used. For this, farmers' perceptions were taken in to consideration under two scenarios, i.e.

Scenario 1: Quantity of ZT demanded at different level of price increase.

Scenario 2: Quantity of ZT demanded at different level of price decline.

3.3.2 (b) An intensive review from the various research papers and different governmental policies was done to examine the diffusion of the zero till technology.

3.3.2 (c) The forecasting of supply/sale was done by the linear trend equation, which is shown below:

$$Y = a + bt$$

Where,

Y = supply/sale of zero till machine from year 1997-2014

a = intercept

b = regression coefficient

t = no. of years

3.3.3 Analytical tool used to achieve second objective

CACP cost concept and Simple average cost of input and returns by adopters and non-adopters of zero till technology of wheat were calculated for the following cost components.

Cost of fertilizer

This is the total amount of money (in Rupee per hectare) spent on fertilizers such as Urea, NPK, and MoP incurred by the farmers. It is the product of unit price of a bag of fertilizer and the total quantity of bags of fertilizer used by the farmers.

Cost of agrochemical

This is the total amount of money (in Rupee per hectare) spent on both pesticide and herbicide used by the farmers during farm operations.

Cost of seeds

This is the total amount of money (in Rupee per hectare) spent on seeds used for planting by the farmers during production season.

Cost of hired labour

This is the total expenditure (in Rupee per hectare) incurred on paid labour by the farmer during farm operations @ Rs 250/day.

Cost of fixed input

This is the total cost on all the fixed input used for farm operation.

Cost of family labour

This is measured as the amount of money which would have been paid for labour if it is hired farm operations. It is measured in Rupees per hectare.

Rental value of owned farm

The rental value of owned farm under wheat production was estimated according to the prevailing rental value of the farms given by the farmers.

CACP Cost concept

Cost A₁ = All variable costs excluding family labour cost and including land revenue, depreciation and interest on working capital.

Cost A₂ = Cost A₁ + Rent paid for leased-in land.

Cost B₁ = Cost A₁ + Interest on the value of owned fixed capital assets (excluding land).

Cost B₂ = Cost B₁ + Rental value of owned land (Net of land revenue).

Cost C_1 = Cost B_1 + Imputed value of family labour.

Cost C_2 = Cost B_2 + Imputed value of family labour.

Cost C_2^* = Cost C_2 estimated by taking into account statutory minimum or actual wage rate, whichever is higher.

Cost C_3 = Cost C_2^* + 10 per cent of cost C_2^* on account of managerial function performed by the farmers.

Note: There was no case of leased-in land, therefore cost A_1 was same as cost A_2 .

Total cost of production

It included operational costs, material costs and fixed costs in wheat crop cultivation. In operational costs the cost of hiring human labour own, machine power were estimated at prevailing rate during study period in the study area. Value of hired labour was computed at actual wage paid in cash or kind and the kind part of payment also was converted into monetary terms at prevailing market price to arrive at actual wage rate. Imputed value of family labour was also calculated using the prevailing wage rate in the study area. The total wage included both cash and kind.

In case of machinery, the hiring charges were applied to all those cases that do not own these and cost of fuel, repairing and maintenance costs were calculated, for those own these. In cases of material cost, cost of seed, manures, chemicals, fertilizers were calculated at prevailing price at the time of application on per ha basis for farmers. Most of farmers used own produced seeds, to compute the cost of own seed, prevailing rate of such seeds in the village at the time of sowing was used.

Fixed costs included interest on value of fixed capital assets, rental value of land and depreciation on value of fixed capital assets. Simple interest was calculated on working capital at flat rate of 7 per cent per annum for the crop duration. Rental value of land prevailed in the study area during study period was taken into consideration. Depreciation on value of fixed capital asset per ha was calculated and included in the cost on the basis of hours used for the crop. Depreciation was

calculated by straight line method on the value of farm building used by the farmer. The compound interest rate of 10% on fixed capital was calculated for both the adopters and non-adopters.

Income measures

These are the returns over different cost concepts. Different income measures are derived using the cost concepts. These measures include farm business income, family labour income, net income, farm investment income, etc. the following formulae were used.

Gross income: Value of total output

Net income

It is computed by deducting cost C_3 from gross income.

Family labour income

It is a measure of earning of a farmer and his family for his labour and managerial work. It is equal to gross income minus total expenses of production excluding wages of the unpaid family labour.

Family labour income = Gross income - Cost B₂

Farm business income

It is measure of earning of farmer and his family for his capital investment labour and managerial work.

Farm business income = Gross income- Cost A₂

Farm investment income

This is the sum of net income, rental value of owned land and interest on fixed capital.

Farm investment income = Net income+ Rental Value of owned land + interest on fixed capital.

Benefit: cost ratio

It reflects the rate of return per unit of investment and presented by:

Benefit: cost ratio = Value of output / Value of input

3.3.4 Analytical tools used to achieve the third objective

To determine the factor influencing the adoption of zero till in rice wheat system following Maddala (1992), Green (2008) and Gujarati (2003) the binary logit model was used:

$$p_i = \frac{1}{1 + e^{-z(i)}}$$

where, P_i is a probability of adoption of conservation tillage technologies for the i^{th} farmer and ranges from 0 to 1. e - Represents the base of natural logarithms and Z_i is the function of a vector of n explanatory variables and expressed.

$$z_i = \beta_0 + \sum \beta_i X_i$$

where, β_0 is the intercept and β_i is a vector of unknown slope coefficients. The relationship between P_i and X_i , which is non-linear, can be written as follows:

$$p_i = \frac{1}{1 + e^{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n}}$$

Finally, the logit model is obtained by taking the logarithm

$$L_i = L_n \left[\frac{p_i}{1 - p_i} \right] = z_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$$

Table 3.3: Description of variables used in the logit model

Variable name	Variable description
Dependent variable	
Adoption of zero till (Y)	1, if adopter , 0 otherwise
Explanatory variables	
Household size (X₁)	No. of the members in family
Age of the farmer (X₂)	In years
Education (X₃)	0= Illiterate, 1= literate
Gender of household head (X₄)	0=female, 1=male
Total farm size (X₅)	Size of the farm available in hectares
Off farm income (X₆)	In ‘000 Rupees
Total farm income (X₇)	In ‘000 Rupees
Source of information (X₈)	1, if formal and 0, if informal

3.4.5 Analytical tool used to attain fourth objective

3.4.5 (a) Economic surplus model given by Alston et al (2005) was estimated as:

$$\Delta CS = PQ Z (1+.5 Z \eta)$$

$$\Delta PS = PQ(K-Z) (1+.5 Z \eta)$$

$$\Delta TS = \Delta CS + \Delta PS = P Q K (1+.5 Z \eta)$$

where, ΔCS is consumer surplus, ΔPS is producer surplus, ΔTS is total surplus i.e. economic surplus, $Z = K \epsilon / (\epsilon + \eta)$; K is vertical shift in supply function as proportion of initial price; η is elasticity of demand (absolute); and ϵ is elasticity of supply.

3.4.5 (b) The environmental benefits realized by adoption of zero till was reduction in carbon emission through the reduced use of diesel. To find out the carbon emission following methodology was adopted:

1 liter Diesel = 2.6 kg of CO₂ (Jat *et al.*, 2006)

1 kg CO₂ = 0.27 kg of carbon (Paustian *et al.*, 2006)





Data collection from individual farmer



Interaction with group of the farmers



View of Zero till Machine



Wheat field sown under zero till condition

PROFILE OF STUDY AREA

This chapter presents the agricultural background of the study area along with its general profile. This chapter is divided into two sections. The first section deals with brief profile of Uttar Pradesh state and the second section deals with a brief description of geographical and agricultural background of Chandauli district. The general features include agrarian statistics, land utilization pattern and agro climatic condition including soil and rainfall. A brief description has also been presented on cropping pattern, agricultural production and some other basic information of the study area.

4.1 Brief profile of Uttar Pradesh state

Uttar Pradesh, with a total area of 243,290 square kilometres, is India's fifth largest state in terms of land area. It is situated on the northern spout of India and shares an international boundary with Nepal. The Himalayas border the state on the north, but the plains that cover most of the state are distinctly different from those high mountains. The larger Gangetic plain region is in the north, it includes the Ganges-Yamuna Doab the Ghaghra plains, the Ganges plains and the *tarai*. The smaller Vindhya range and plateau region is in the south. It is characterised by hard rock strata and a varied topography of hills plains, valleys and plateaus. The Bhabhar tract gives place to the terai area which is covered with tall elephant grass. The entire alluvial plain is divided into three sub-regions the first in the eastern tract consisting of 14 districts which are subject to periodical floods and droughts and have been classified as scarcity areas. These districts have the highest density of population which gives the lowest per capita land. The other two regions, the central and the western are comparatively better with a well-developed irrigation system. The state has more than 32 large and small rivers; of them, the Ganges, Yamuna, Saraswati, Sarayu, Betwa, and Ghaghara are larger and of religious

importance in Hinduism Cultivation is intensive. The valley areas have fertile and rich soil. There is intensive cultivation on terraced hill slopes, but irrigation facilities are deficient. The transitional belt running along the entire length of the state is called the *terai* and *bhabhar* area. It has rich forests, cutting across it are innumerable streams which swell into raging torrents during the monsoon. Uttar Pradesh has a humid temperate climate and experiences four seasons. The winter in January and February is followed by summer between March and May and the monsoon season between June and September. Summers are extreme with temperatures fluctuating anywhere between 0 °C and 50 °C in parts of the state. The Gangetic plain varies from semiarid to sub-humid. The mean annual rainfall ranges from 650 mm in the southwest corner of the state to 1000 mm in the eastern and south eastern parts of the state. Primarily a summer phenomenon, the Bay of Bengal branch of the Indian Monsoon is the major bearer of rain in most parts of state. It is the South-West the rain in U.P. can vary from an annual average of 170 cm in hilly areas to 84 cm in Western U.P. Given the concentration of most of this rainfall in the 4 months of Monsoon period, excess rain can lead to floods and shortage to droughts. As such, these two phenomena, floods and droughts, commonly recur in the state. Typical summer months are from March to June, with maximum temperatures ranging from 30 to 38 °C (86 to 100 °F). There is low relative humidity of around 20 per cent and dust-laden winds blow throughout the season. Uttar Pradesh has both a large population and a high population growth rate. During the decade from 1991 to 2001 its population increased by over 25.8 per cent. Uttar Pradesh is also the most populous state in India with a population of 199,581,477 people as of 1 March 2011. The state contributes 16.16 per cent of India's population. The population density is 828 people per square kilometre, making it one of the densest states in the country. The sex ratio as of 2011, at 908 women to 1000 men, is lower than the national figure of 933. The state's 2001–2011 decennial growth rate was 20.09 per cent, higher than the national rate of 17.64 per cent. The literacy rate of the state according to the 2011 Census is 70 per cent, which is below the national average of 74 per cent. While the literacy rate for men

is at 79 per cent, it is 59 per cent for women. In 2011, the literacy rate in Uttar Pradesh stood at 56.27 per cent overall, and 67 per cent and 43 per cent for men and women, respectively.

There are 4 economic zones, 9 agro climatic zones, 18 administrative divisions, 83 districts, 901 developmental blocks and 84000 gram panchayats in the state.. Uttar Pradesh is the third largest economy state in India (8 per cent) and having the GSPD of 74.1 USD billion.

4.2 Geographical and agricultural background of Chandauli district

4.2.1 Location

The present study was conducted in Chandauli district The district Chandauli is located in 24° 56' to 25° 35' to north and 81° 14' to 84° 24' east at a distance. It comes under Varanasi division distance of about 30 kms east-south-east of Varanasi. Chandauli is bounded on east by Bihar State, on the north-north-east of Ghazipur district, South of Sonbhadra district, South-east of Bihar and South-West Mirzapur. From the view point of administration, the district has been divided into three 'Tehsils' and nine 'blocks.' The district contributes to Indian GDP by providing the various cereals from the district including paddy and wheat. Chandauli is popularly known as the rice bowl of Uttar Pradesh because of extreme fertile lands of the Gangetic Plain.

4.2.2 Demographic profile of Chandauli district

According to the 2011 census Chandauli district has a population of 19573163. Total population of male was 1020290 and of females was 937070. The literacy rate was 78.9 per cent. Total number of villages was 1637. The district has a population density of 768 inhabitants per square kilometre.

Table 4.1: Demographic features of Chandauli district (2013-14)

S.No.	Particulars	Unit	Figures
1.	Total geographical area	Square Km.	2541
2.	Population	In 000	1957.36
	Male	In 000	1020.29
	Female	In 000	937.07
3.	Population density	Numbers	768
4.	Village	Numbers	1637
5.	Literacy	Per cent	78.9
	Male	Per cent	83.58
	Female	Per cent	63.07

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

4.2.3 Topography

This district covers 351958 Km. Sq. Area. On the basis of geology, soils, topology, climate and natural vegetation the district is subdivided in the following regions:

1. Chakia Plateau
2. Chandauli Plain
3. Ganga Khadar

Chakia Plateau is comprised of southern part of Chakia tahsil. The 100 meter contour separates the region from Chandauli Plain. This small patch is suitable for agriculture. Paddy is the main crop which is cultivated here. Geologically the region belongs to upper proterozoic period. Chandauli Plain comprises parts of Chandauli, Sakaldiha and Chakia Tahsil. The area under Chandauli tahsil is comparatively low which causes water logging during rainy season. Ganga Khadar is narrow belt along the Ganga river extending from one end of the district to the other end.

4.2.4 Agro-climatic features

4.2.4.1 Soil and climate

There is variation in soil and climate in the district, block and even at village level. The most common soil types in the district are:

(1) Alluvial Soil, (2) Calcareous soil, and (3) Rocky Track.

Alluvial soil have characteristics of sandy, sandy loam or clay loam whereas calcareous soil has property of black soil and Rocky track characterised by sandy loam with small stones with an average rainfall of 667 -1153 mm, temperature 6 to 44 °C.

4.2.4.2 Rainfall

The total rainfall varies from 926.4 mm to 17.5 mm .Out of total rainfall 85 - 90 per cent is concentrated in monsoon period June to September. Normal rainy days in SW monsoon (June-Sept.) was 39, NE monsoon (Oct.-Dec.) is 3, Winter (Jan-March) was 4, Summer (Apr-May) is 2 and total normal rainy days were 48 with 1056.4 mm rainfall.

4.2.5 Agricultural economy of Chandauli district

4.2.5.1 Land utilization pattern of Chandauli district

The land utilization pattern of Chandauli district has been represented in the table 4.2. From the table it is evident that the total area was 253374 ha. Total area under forest was 77400 hectares accounting 30.54 per cent total area.

Table 4.2: Land utilization pattern of Chandauli district

Land use	Area (ha)	Per cent
Total area	253374	100
Forest	77400	30.54
Barren cultivable waste	1107	0.43
Present fellow land	7508	2.96
Other fellow land	1699	0.67
Barren & uncultivable land	2762	1.09
Land put to non-agri use	25779	10.17
Pastures	28	0.01
Area under bush, forest & garden	1148	0.45
Net area sown	135943	53.65
Area sown more than once	108704	42.90
Gross sown area	244647	96.55

Source: Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

Table also shows that the Land put under non-agricultural use accounted for 25779 ha that is 10.74 per cent of total area. About 135943 ha (53.65 per cent) area covered net sown area, 108704 ha area covered under area sown more than once and share of gross sown area was 244647 ha (96.55) of total area.

4.2.5.2 Distribution of operational holdings in Chandauli district

The distribution of operational holding is shown in table 4.3. The table reveals that land holdings are mostly less than 0.5 ha (65.06 per cent) while area accounted for 30.77 per cent out of total area while the farmers having more than 10 ha land accounts 0.091 per cent number and 1.62 per cent area out of total area in Chandauli district.

Table 4.3: Distribution of operational holdings in Chandauli district

Land holding (in ha)	Number	Per cent	Area (in ha)	Per cent
Less than 0.50	128999	65.06	44761	30.77
0.50 to 1.00	39640	19.99	31689	21.79
1.00 to 2.00	17376	8.76	24861	17.09
2.00 to 4.00	8971	4.52	24801	17.05
4.00 to 10	3088	1.55	16952	11.65
10 or more	181	0.091	2360	1.62
Total Number	198255	100	145424	100

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

4.2.5.3 Irrigation: Source wise area irrigated

Table 4.4 shows that the irrigation facilities available in Chandauli district for the year 2013-14. Total irrigated area in the district was 127568 ha. Among the different source of irrigation, canal is the major source of irrigation that account for 82.75 per cent of total irrigated area. Tuve wells accounts for only 15.4 per cent of total irrigated area.

Table 4.4: Distribution of irrigated area (ha) by sources

Source	Total irrigated area (ha)	Per cent
Canal	105565	82.75
Tube wells	19654	15.4
Wells	450	0.35
Others	1834	1.43
Total	127568	100

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

4.2.5.4 Cropping pattern

The cropping pattern of Chandauli district for the year 2010-11 is presented in the table 4.5. The table indicates that about 97.48 per cent and 87.21 per cent area is under food grains in kharif and rabi season respectively. Rice is the main crop of kharif accounted for about 91 per cent area to total cropped area in kharif season. Looking the coverage of rice, it seems rice cultivation is a major economic activity of farmers in the district. Similarly wheat is important crop in rabi season accounted for about 86 per cent area to total cropped area in rabi. The other crops such as oilseed, pulses, sugarcane and fodder etc. have little importance in terms of area allocation by the farmers.

Table 4.5 Cropping pattern in the Chandauli district during 2013-14

S.No.	Crops	Area (ha)	Per cent to the total cropped area
Kharif			
1.	Rice	111777.00	90.75
2.	Maize	96.00	0.07
3.	Jowar	1714.00	1.39
4.	Bajra	6482.00	5.26
Total Cereal		120069.00	97.48
5.	Urd	100.00	0.08
6.	Moong	34.00	0.02
7.	Pigeon pea	2938.00	2.38
Total pulses		3072.00	2.49
8.	Groundnut	3.00	0.01
9.	Til	17.00	0.01
Total oilseed		20.00	0.01
Grand Total		123161.00	100.00

Contd..

S.No.	Crops	Area (ha)	Per cent to the total cropped area
Rabi			
1.	Wheat	97225.00	86.31
2.	Barley	1006.00	0.89
Total Cereal		98231.00	87.21
3.	Gram	1810.00	1.60
4.	Pea	1889.00	1.67
5.	Masoor	9382.00	8.32
Total Pulses		13081.00	11.61
6.	Mustard	365.00	0.32
7.	Alsi	964.00	0.85
Total oilseed crop		1329.00	1.17
Grand Total		112641.00	100.00

Source: Khadyan Utpadan Karyakram (*rabi* and *kharif*), Chandauli district (2013-14)

Among cereals crops, the highest cropped area was occupied by rice (90.757 per cent) in kharif season and wheat in rabi season (86.31 per cent) followed by bajra (5.26 per cent), jowar (1.39 per cent), Maize (0.077 per cent) in kharif and barley (0.89 per cent) in rabi season. Among pulses pigeon pea (2.38 per cent) had highest area followed by Urd (0.08 per cent), moong (0.02 per cent) in kharif season while in rabi season masoor (8.32 per cent) occupies highest area followed by pea (1.667 per cent), gram (1.6 per cent). In oilseeds til (0.013 per cent) occupies highest area followed by groundnut (0.002 per cent) in kharif season and in rabi season alsi (0.855 per cent) has highest area followed by mustard (0.324 per cent).

4.2.5.5 Distribution of livestock in Chandauli district

Livestock formed a sustainable source of income for household. Table 4.6 represents the category wise livestock population in Chandauli district. From table 4.6 it was spotted that crossbred cattle contributes 5.2 per cent, indigenous cattle give 47.84 per cent and buffalo contributes 46.89 per cent to the total milch animals (cattle and buffalo),

sheep and goat add up 22.06 per cent and 77.93 per cent to the small ruminants crossbred pig was 6.8 per cent while indigenous pig was 93.19 per cent of total pig population. In poultry broiler and cheeks were 86.39 per cent and ducks contributes 13.05 per cent. Fish covers 5907 ha water spread area.

Table 4.6: Distribution of livestock in Chandauli district

S. No.	Category	Population	Per cent to the total population
1.	Cattle		
a.	Crossbreed	17203.00	5.20
b.	Indigenous	156377.00	47.84
2.	Buffalo	153258.00	46.89
	Total	326838.00	100.00
3.	Sheep	23421.00	22.06
4.	Goat	82704.00	77.93
	Total	106125.00	100.00
5.	Pig		
a.	Crossbreed	510.00	6.80
b.	Indigenous	6989.00	93.19
	Total	7499.00	100.00
6.	Poultry		
a.	Broiler & Cheeks	184353.00	86.39
b.	Duck	29032.00	13.05
	Total	213385.00	100.00
7.	Fish	5907.00 ha (Water spread area)	

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

4.2.5.6 Farm implements and machinery

The details of farm implements and machinery in the district Chandauli was given in table 4.7.

Table 4.7: The details of farm implements and machinery in the district Chandauli

Particular	Number	Per cent
Desi plough	13195	30.05
Iron Plough	8435	19.21
Harrow and cultivator	3404	7.75
Thrasher	11594	26.40
Sprayer	591	1.34
Seed Drill	612	1.39
Tractor	6078	13.84
Total	43909	100

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

Table 4.7 showed that the number of equipment and machinery in the district Chandauli. Tractor is one of the important implement in the modern era by which farming business becomes fully mechanized. Other supporting implement and machineries are desi plough, iron plough, harrow and cultivator, thresher, sprayer and seed drills. It is very obvious from the table that only 13.84 per cent of the total implements accounted for tractors while 30.05 per cent accounted for desi plough. It seems that the majority of farmers are not resource rich to owe with mechanization and tractors while they were very much inclined to desi plough and subsistence type of techniques rather modern farm techniques.

4.2.5.7 Distribution of fertilizer

Table 4.8: Distribution of fertilizer during year 2013-14 in Chandauli district

Particulars	Total Distribution (in metric tonnes)	Per cent of total distribution
Nitrogen	26050	72.92
Phosphorus	8815	24.67
Potash	859	2.40
Total	35724	100

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

It is evident from table 4.8 that total fertilizer distribution in Chandauli district was 35724 metric tonne during the year 2013-14. Total nitrogen use in this district was maximum 26050 metric tonne (72.92 per cent), then phosphorus 8815 metric tonne (24.67 per cent) and potash 859 metric tonne (2.40 per cent).

4.2.5.8 Public health centers

Health is another important factor in achieving general human welfare which is more important for good crop production also. Healthy person can perform their duties more efficiently as compared with ill health persons. There were 53 health centres available in the district.

Table 4.9: Public health centers in the year 2013-14 in Chandauli district

Type of health centers	Number	Per cent to total
Ayurvedic	31	58.49
Unani	1	1.88
Homeopathic	21	39.62
Total	53	100

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

4.2.5.9 Educational Institutions

Education is the most important single factor in achieving rapid economic development and increasing social order founded on the value of freedom, social justice and equal opportunity. Educational institutions are competent tools of rural transformation.

Table 4.10: Educational institutions during year 2013-14 in Chandauli district

Type of institution	Number of institutions
Primary School	1275
Higher Primary School	672
Secondary school	196
Total	2143

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14

It was revealed from table 4.10 that there are 1275 primary school, 672 higher primary school and higher secondary school situated in Chandauli district.

4.2.5.10 Financial institutions

Presence of financial institutions in the area having proved beneficial to the farmers, who help financial need to the farmers on lower interest rate from the government bank for convenient period. Different type of financial institutions for the benefit of the farmers in the Chandauli district showed in table 4.11.

Table 4.11: Financial institutions during 2013-14 in Chandauli district

Type of the banks	Number of branches
Nationalized banks	73
Rural bank	48
Non-commercial nationalized bank	17

Source: Statistical Bulletin, Chandauli district, Uttar Pradesh, 2013-14



RESULTS AND DISCUSSION

This chapter has been devoted to the presentation of results and discussion of the findings of the study. The discussion of the results of the study is followed by economic interpretations and suggestive inferences. The results are in accordance with the objectives of the study:

- 5.1 Elicit and characterize farmer's demand and diffusion for zero till and its forecasting in the rice wheat cropping system.
- 5.2 Economics of wheat under RCT
- 5.3 Relative importance of the various factors influencing adoption of Resource Conservation technology.
- 5.4 Assessment of the economic and environmental impacts of zero tillage.

5.1 Elicit and characterize farmer's demand and diffusion for zero till and its forecasting in the rice wheat cropping system

5.1.1 Elicit and characterize farmer's demand for zero till in the rice wheat cropping system

- a) **Under price increase scenario:** Farmer's perceptions were recorded under the price increase scenario in different range and it was assumed that all the other things remain constant like income, allocation of area under wheat, technological changes etc.

From the sample size of the 52 adopters, only 16 farmers had their own zero till machine, remaining adopters (36) were in the category of custom hiring. It is revealed from the table 5.1 that adopters can tolerate the price increase up to 20 per cent from the existing price of Rs. 20,000. If the prices were increased by more than 40 per cent then there won't be any demand of zero till and the number will go zero. If there was an increase in a price by 40-50 per cent then it can be interpreted as that with the 1 per cent increase in

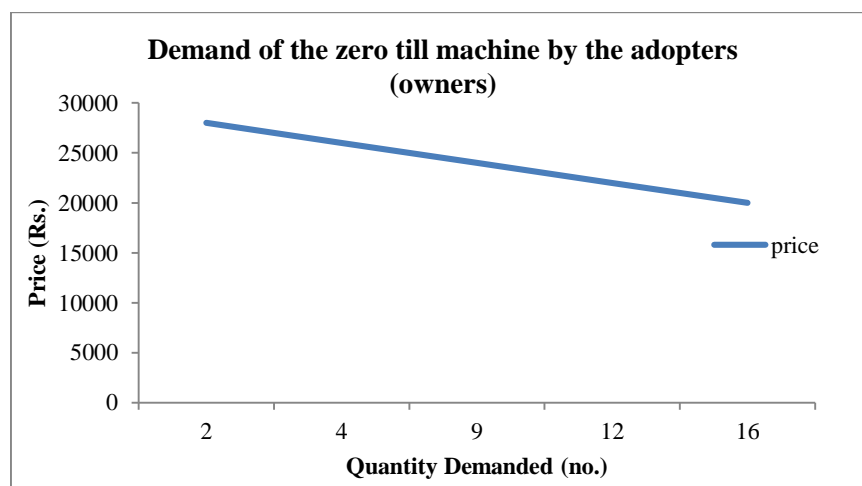
the price the demand for zero till will go down by 14 per cent. In case of custom hiring adopters and non-adopters, they were not interested in the purchase of new machine at these prices. On the basis of the demand elasticity it is suggested that in future manufacturer or supplier should not increase zero till machine cost/price beyond 20 per cent of the existing price.

Table 5.1: Demand and elasticity's of zero till (when prices increase)

Increase in prices (%)	Demand of machine by adopters (owners)	Elasticity of demand
0%	16	-
10%	12	-2.50
10-20%	9	-2.75
20-30%	4	-6.67
30-40%	2	-6.50
40-50%	0	-14.00

Source: Based on Farmers perception

Figure 5.1: Demand of zero till machine when price increases



- b) **Under price decrease scenario:** Farmer's perceptions were also recorded under the scenario of decrease in prices of zero till machine and it was assumed that all the other things remain constant like income, allocation of area under wheat, technological changes etc.

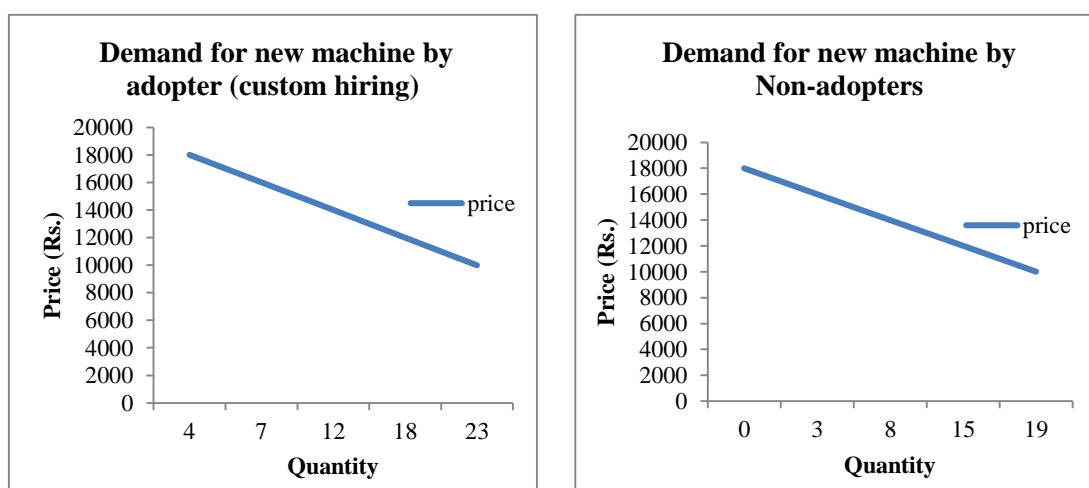
Those farmers who have purchased and own zero till machine, during survey it was found that the machine was purchased during or between years 2000 - 2003. This number is 16 which were assumed constant irrespective of the price change, since, it was revealed by the respondents that old machines have to be replaced by new machines because of expected life of machine i.e. 12 years, therefore on the basis of the respondents perception it was decided that the under this category quantity will remain same.

Table 5.2: Demand and elasticity's of zero till (when prices decrease)

Decrease in prices (%)	No. of adopters	Elasticity	New adopter cum owners	Elasticity	Non adopter cum owners	Elasticity	Aggregate demand	Elasticity
0%	16	0.00	0	0.00	0	0.00	16	0.00
10%	16	0.00	4	0.00	0	0.00	20	2.50
10-20%	16	0.00	7	6.75	3	0.00	26	2.70
20-30%	16	0.00	12	5.71	8	13.33	36	3.08
30-40 %	16	0.00	18	3.50	15	6.13	49	2.53
40-50%	16	0.00	23	1.67	19	1.60	58	1.10

Source: Based on Farmers perception

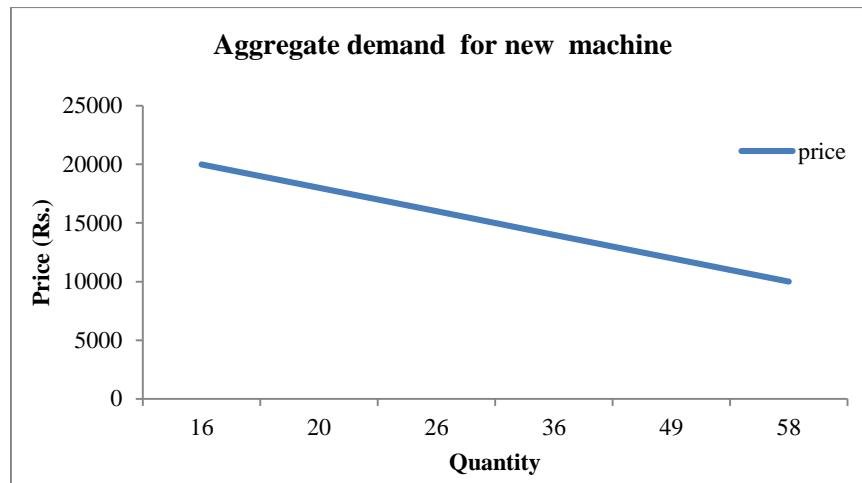
Figure 5.2 (A) and (B): Demand curve of zero till machine by adopters (custom hiring) and by non - adopters



(A)

(B)

Figure 5.3: Aggregate demand curve of zero till machine by adopters, adopters cum new owners and by non-adopters cum new owners



There were 36 per cent adopters who were using Zero till on custom hiring but they were in favour of that if prices will go down, they were prefer to purchase (own) machine rather than custom hiring. It is evident from table 5.2 that if there is a very slight decrease i.e. only 10 per cent (Rs. 2000) at least 4 farmers/adopters were interested to purchase the machine but when the prices go beyond 40-50 per cent then out of 36 custom hiring adopters 23 adopters showed their interest to purchase the zero till machine.

Table 5.2 indicated that when prices go down by only 10 per cent no non-adopter were interested in owning of machine but when price were decreased by 10-20 per cent then 3 non-adopters showed interest to purchase the machine but the elasticity up to this point was found zero but with further decrease of 40-50 per cent out of 48 non-adopters 19 wanted to be the owner of the machine.

The analysis of the table 5.2, depicted that when we see the aggregate demand out of both adopters and non-adopters (100 sample size), it was found that 58 farmers were interested to purchase the zero till machine, when the price go beyond 40-50 per cent. The aggregate elasticity at this point was found 1.10. Maximum elasticity was found in the range of 20-30 per cent price decline, therefore, it is recommended that

about Rs. 5000 to 6000 on in the existing price is more appropriate to increase sale and adoption of zero till.

It was suggested that government and manufacturer should work together to popularize zero till. From manufacturer side the effort should be made for cost reduction and from government side incentives/subsidy and an effective extension mechanism should be promoted.

5.1.2 A journey of diffusion of zero till technology

According to Rogers, “Adoption process is the mental process through which an individual passes from hearing about an innovation to final adoption” whereas “Diffusion is the spread of a new idea from its source of invention or creation to its ultimate users or adopters”. These definitions indicate that diffusion is a process related to adoption of an innovation in an entire social system such as a village or block, while adoption is a sequence of thoughts and actions which an individual goes through, before he finally adopts a new idea.

In India, research on ZT for wheat started almost three decades ago (Ekboir 2002). Several state agricultural universities tried ZT in the 1970s but their efforts failed due to technical difficulties, such as the lack of adequate planting equipment and the difficulty in controlling the weeds chemically. This line of research was soon abandoned by all except a handful of researchers working in isolation. In 1990, CIMMYT’s regional wheat agronomist introduced inverted-T openers to Indian researchers. These openers were originally developed in New Zealand by Aitchison Industries in 1988. In 1991, a first prototype of the Indian ZT seed drill was developed at G. B. Pant University of Agriculture and Technology, Pantnagar. In 1992–93, a collaborative program for further development and commercialization of ZT was initiated with small-scale industries in Punjab (throughout this report, this means Indian Punjab). After considerable investment of resources and several design changes, the first ZT seed drill was made available for field testing within 12 months. The RWC joined hands with the National Agricultural Research Systems and

provided support to pursue farmers' participatory research and further adapt the zero-tillage technology to rice-wheat systems. To overcome bureaucratic hurdles, RWC acquired several zero tillage drills and donated them to the Haryana Agricultural University for experimenting in farmers' fields. This provided the much-needed push to this program. In the late 1990s, Monsanto supported no till research at the universities but soon reduced its activities as the potential market for their product, glyphosate, was perceived as small. In 1997, after further refinement based on the feedback received from scientists and farmers, the private manufacturers supplied over 150 improved ZT drill machines to State Agricultural Universities (SAU) and the Indian Council for Agricultural Research (ICAR) institutions located in Haryana, Punjab, Uttar Pradesh, and Bihar.

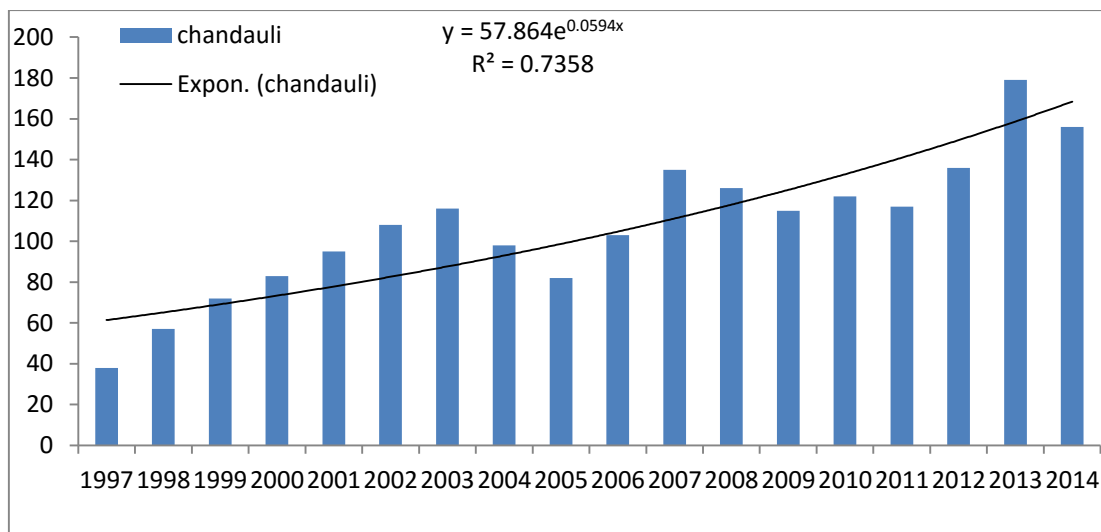
The zero till technology in wheat after harvesting of rice was introduced first time during Rabi 2001- 02 by NDUAT, Kumarganj, Faizabad on massive scale in Eastern Uttar Pradesh by covering 550 ha area of 290 farmers belonging to 17 districts. After getting encouraging results, the area further expanded by 1430 ha (2002-03) and 9510 ha (2003-04) due to adoption of technology by 835 and 3822 farmers, respectively.

It is concluded that the diffusion of zero till is very slow during the period of about two decades ago.

5.1.3 Forecasting of supply/sale zero till machine in Chandauli district

The growth trend analysis of supply/sale of zero till machine in Chandauli district showed the positive and significant results at 1per cent level of significance and it was growing with 6per cent per annum (figure 5.4). The forecasting of supply or sale of zero till was done for three year i.e. period from year 2015 to 2017 with the help of linear trend equation. The results of the analysis depicted that the supply is increasing every year. The results of forecasting showed that in year 2015, 2016 and 2017 the sale of zero till may be 162,168 and 173 units per year respectively.

Figure 5.4: Compound annual growth rate of zero till machine in Chandauli district

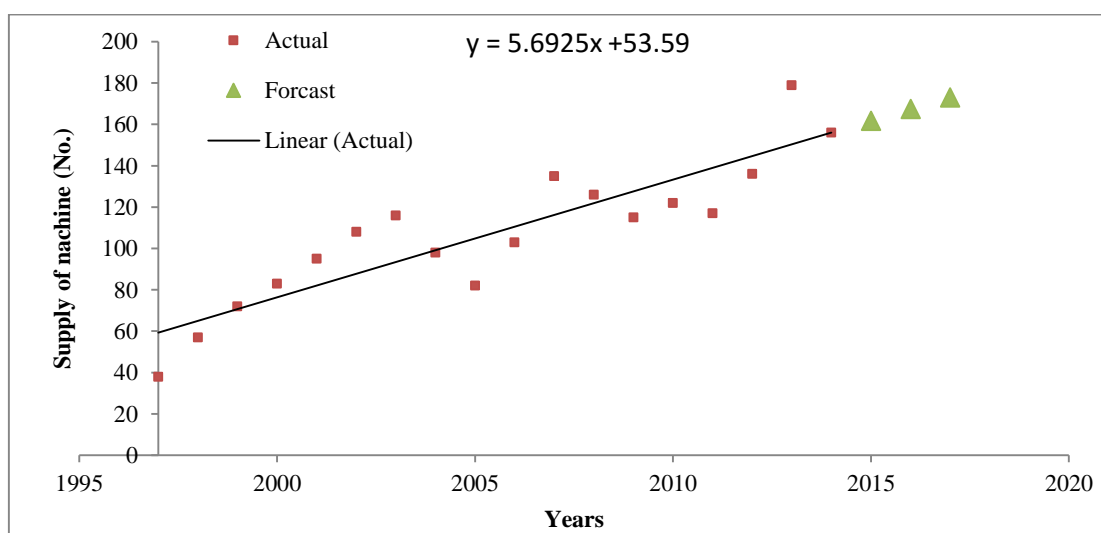


Source: calculated on the data collected from DSB

Table 5.3: Forecasting for the supply of zero till in Chandauli

Year	Forecasting (in nos.)
2015	161
2016	167
2017	173

Figure 5.5: Forecasting for the supply of zero till in Chandauli



5.2 Economics of wheat under RCT

The per ha economics of wheat crop cultivation in Eastern Uttar Pradesh for both adopters and non- adopters of resource conservation technology i.e. zero till is presented in table 5.4. It was evident from the table that the average, per ha cost of cultivation of wheat for adopters was Rs. 49199 of which Rs. 24711 (50.2 per cent) was operational cost and Rs. 20015 (40.7 per cent) was fixed cost while for non-adopters the total cost was Rs. 56002 of which Rs. 30649 (54.7 per cent) was operational cost and Rs. 20261(36.2 per cent) was fixed cost. In the case of adopters the cost of cultivation was observed higher on small farms (Rs. 49805) followed by large farms (Rs. 49062) and medium farms (Rs. 48729), on the farms of non-adopters the maximum cost of cultivation was found for large farms (Rs. 56123) followed by small farms (Rs. 55976) than medium farms (Rs. 55906).

As per the economic theory, economies of scale operate as farm size increases; the operational cost under adopter category was Rs. 25277 in small farms, Rs. 24289 in medium farms and Rs. 24567 in large farms for adopters. Likewise in case of non-adopters operational cost was Rs. 31197, Rs. 30439 and Rs. 30311 on small, medium and large farms respectively.

Share of various costs in wheat cultivation as depicted in table 5.4 under adopter category, fertilizer was found one of the major component in operational cost, contributing to 13.4 per cent (Rs. 6610) of the total cost followed by irrigation charges, human labour, seed and tractor charges i.e. 11.1 per cent (Rs. 5540) , 10 per cent (Rs. 4917), 6.8 per cent (Rs. 3335) and 6.5 per cent (Rs. 3200) respectively. Cost on labour, tractor and seed constitute maximum proportion i.e. 10.2 per cent, 6.9 per cent and 6.9 per cent respectively in case of small farms, fertilizer and plant protection chemicals charges found high for medium farms i.e. 13.7 per cent and 1.6 per cent but the use of irrigation (11.2 per cent) was found more on large farms. Family labour contributes high on small farms followed by medium and large farms. Whereas hired labour contribution increased with increase in size of the farm. Total

fixed cost per ha was found higher Rs. 20035 on large farms as compared to other groups. Rental value of owned land was the only important component contributing 34.3 per cent of the total cost. Rental value of leased land increased with the increase in the size of farm. Interest on average fixed capital was worked out to be Rs. 2583 (5.3 per cent) per hectare. Several studies have also shown that ZT method of wheat production provides several benefits such as saving of irrigation water, reduction in production cost, less requirement of labour and timely establishment of crops, resulting in improved crop yield and higher net income (Laxmi et al., 2007, Farooq et al., 2006, Erenstein et al., 2007).

On the basis of the above results, it may be concluded that small farmers are putting more human resources despite the use of resource conservation technology; it is because of availability of family labour, while medium farmers are paying attention on fertilizer use and large farmers are using more irrigation facility.

In case of non-adopters there is nominal difference in the pattern of expenses of seed, fertilizer, plant protection chemicals, irrigation and tractor use except human labour. The share of human labour expenditure was found to be higher on small farms, because of availability and use of family labour.

Table 5.4: Cost of cultivation of wheat on adopters and non-adopters (Rs./ha.)

Items	Adopters (N=52)				Non-Adopters (N=48)			
	Small	Medium	Large	Overall average	Small	Medium	Large	Overall average
Operational Cost								
Family Labour	1250 (2.5)	750 (1.5)	250 (0.5)	750 (1.5)	3000 (5.4)	1500 (2.7)	1000 (1.8)	1833 (3.3)
Hired Labour	3850 (7.7)	4100 (8.4)	4550 (9.3)	4166 (8.5)	5100 (9.1)	5950 (10.6)	6550 (11.7)	5867 (10.5)
Total Human Labour	5100 (10.2)	4850 (10.0)	4800 (9.8)	4917 (10.0)	8100 (14.5)	7450 (13.3)	7550 (13.5)	7700 (13.7)
Machinery Charges	3450 (6.9)	3000 (6.2)	3150 (6.4)	3200 (6.5)	5400 (9.6)	5400 (9.7)	5100 (9.1)	5300 (9.5)
Seed	3445 (6.9)	3254 (6.7)	3308 (6.7)	3335 (6.8)	3540 (6.3)	3450 (6.2)	3420 (6.1)	3470 (6.2)
Irrigation	5540 (11.1)	5329 (10.9)	5484 (11.2)	5451 (11.1)	5519 (9.9)	5473 (9.8)	5528 (9.9)	5507 (9.8)
Plant Protection Chemical	752 (1.5)	781 (1.6)	788 (1.6)	774 (1.6)	781 (1.4)	777 (1.4)	776 (1.4)	778 (1.4)
Fertilizer	6557 (13.2)	6659 (13.7)	6615 (13.5)	6610 (13.4)	7322 (13.1)	7366 (13.2)	7416 (13.2)	7368 (13.2)
Total working capital	24843 (49.9)	23872 (49.0)	24145 (49.2)	24287 (49.4)	30661 (54.8)	29916 (53.5)	29790 (53.1)	30123 (53.8)
Interest on working capital	435 (0.9)	418 (0.9)	423 (0.9)	425 (0.9)	537 (1.0)	524 (0.9)	521 (0.9)	527 (0.9)
Subtotal	25278 (50.8)	24290 (49.8)	24567 (50.1)	24712 (50.2)	31198 (55.7)	30439 (54.4)	30312 (54.0)	30650 (54.7)
Fixed capital								
Land revenue	60 (0.1)	60 (0.1)	60 (0.1)	60 (0.1)	60 (0.1)	60 (0.1)	60 (0.1)	60 (0.1)
Rental value of owned land	17690 (35.5)	16650 (34.2)	16225 (33.1)	16855 (34.3)	17380 (31.0)	16875 (30.2)	16750 (29.8)	17002 (30.4)
Depreciation	375 (0.8)	550 (1.1)	625 (1.3)	517 (1.1)	375 (0.7)	575 (1.0)	650 (1.2)	533 (1.0)
Interest on fixed capital	1875 (3.8)	2750 (5.6)	3125 (6.4)	2583 (5.3)	1875 (3.3)	2875 (5.1)	3250 (5.8)	2667 (4.8)
Sub total	20000 (40.2)	20010 (41.1)	20035 (40.8)	20015 (40.7)	19690 (35.2)	20385 (36.5)	20710 (36.9)	20262 (36.2)
10 % managerial cost	4528 (9.1)	4430 (9.1)	4460 (9.1)	4473 (9.1)	5089 (9.1)	5082 (9.1)	5102 (9.1)	5091 (9.1)
TOTAL	49806 (100)	48730 (100)	49063 (100)	49199 (100)	55977 (100)	55907 (100)	56124 (100)	56002 (100)

Figures in parenthesis indicates percentage of cost of cultivation of wheat

Figure 5.6: Expenditure of adopters and non-adopters on different inputs

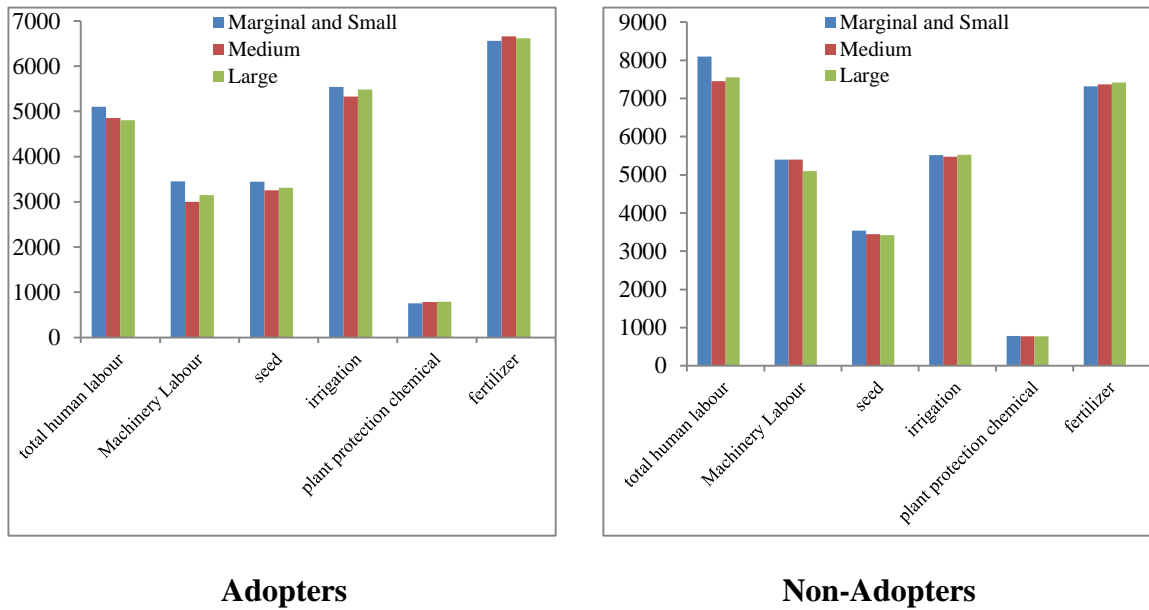
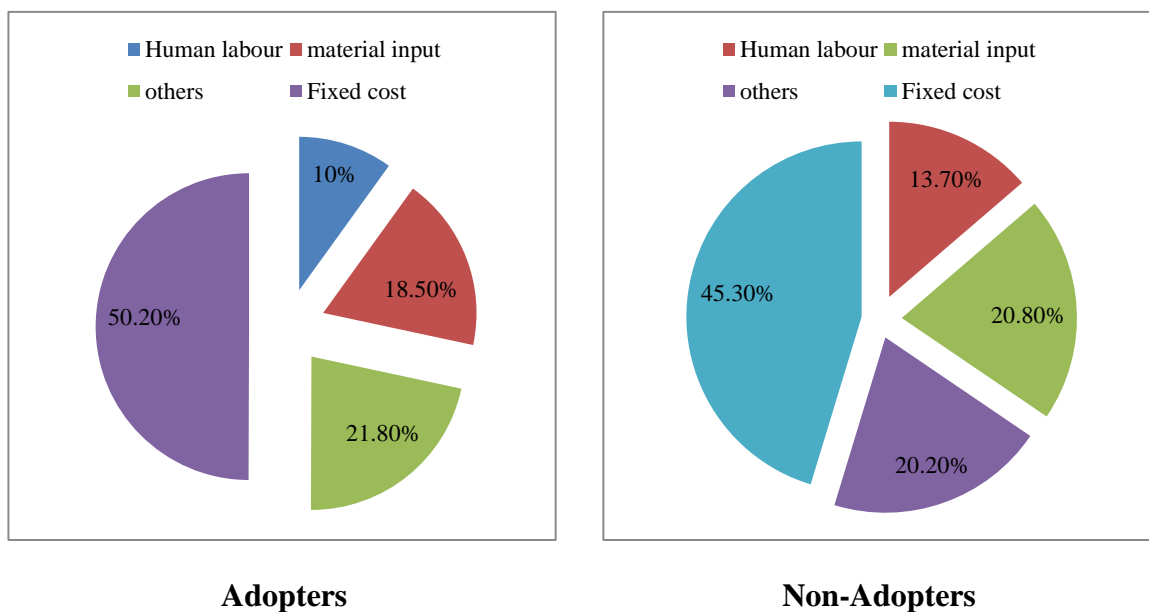


Figure 5.7: Overall average share of different cost in case of adopters and non-adopters



5.2.1 Cost and returns in case of adopters and non-adopters

Cost of cultivation for adopters and non-adopters are given in table 5.5. The average total cost of cultivation i.e. cost C_3 is estimated to be Rs. 49199 per ha and Rs. 56002 per ha for adopters and non-adopters respectively. It was evident from table that the cost A_1 i.e. direct cost involved in wheat cultivation was Rs. 24538 per ha for adopters and Rs. 29410 per ha for non-adopters. In the study area there was no leased -in land so cost A_1 was equal to cost A_2 . It was observed that cost B_1 was Rs. 27121 per ha and Rs. 32076 per ha for adopters and non-adopters, respectively. Cost B_2 contributed Rs. 43976 per ha and Rs. 49078 to the cost C_3 for adopters and non-adopters, respectively. Cost C_1 , C_2 and C_2^* work out to be Rs. 27871, Rs. 44726 and Rs. 44726 per ha for adopters and for non-adopters it was Rs. 33910, Rs. 50911 and Rs. 50911 per ha, respectively.

On an average adopters and non-adopters farms, got 42.1 quintals of wheat and 43 quintal straw per ha and 38 quintals and 40 quintals respectively, from wheat cultivation (table 5.5). Zero till for wheat was most successful in terms of crop establishment (Ladha et al., 2009) and gain in yield ranging from 1 per cent to 12 per cent (Erenstein and Laxmi, 2008). Overall gross income in wheat cultivation was worked out to be Rs. 65530 for adopters but for non-adopters it was Rs. 59229 per hectare. It was observed from table that net return over cost A_1 and A_2 , B_1 , B_2 , C_1 , C_2 , C_2^* and C_3 was found to be positive which revealed that farmers had covered his all cash and kind expenses which were incurred in the production of wheat crop, but results also indicate that there was a huge difference in their returns i.e. in case of adopters the net return over cost C_3 found to be Rs. 16330 which was much more higher than the non-adopters returns i.e. Rs. 3226. Similar results have been reported by many other studies conducted on this aspect and explained the fact that the net revenue in wheat production was significantly higher under zero till than under conventional method (Erenstein et al., 2007, Iqbal et al., 2002, Tripathi et al., 2013).

Overall farm business income, family income and farm investment income for adopters and non-adopters in wheat production was worked out to be Rs. 41065, 21553, 35768, 29818, 10150 and 22894, respectively.

Table 5.5: Cost and returns in case of adopters and non-adopters

Items	Adopters				Non-Adopters			
	Small	Medium	Large	Overall Average	Small	Medium	Large	Overall Average
Cost A ₁	24462	24149	25002	24538	28632	29574	30021	29410
Cost A ₂	24462	24149	25002	24538	28632	29574	30021	29410
Cost B ₁	26337	26899	28127	27121	30507	32449	33271	32076
Cost B ₂	44027	43549	44352	43976	47887	49324	50021	49078
Cost C ₁	27587	27649	28377	27871	33507	33949	34271	33910
Cost C ₂	45277	44299	44602	44726	50887	50824	51021	50911
Cost C ₂ *	45277	44299	44602	44726	50887	50824	51021	50911
Cost C ₃	49805	48729	49062	49199	55976	55906	56123	56002
Yield and Income								
Main product (qtl/ha)	40.7	42.5	43	42.1	37.58	37.42	37.87	38
By product (qtl/ha)	42.4	42	44.6	43	39.8	40.2	40.69	40
Price of main product	1200	1200	1200	1200	1200	1200	1200	1200
price of by product	350	350	350	350	350	350	350	350
Returns								
Return from main product	48840	51000	51600	50480	45096	44904	45444	45148
Return from by product	14840	14700	15610	15050	13930	14070	14241	14081
Gross return	63680	65700	67210	65530.0	59026	58974	59685	59229
Cost A ₁	39217	41550	42207	40991	30393	29399	29663	29818
Cost A ₂	39217	41550	42207	40991	30393	29399	29663	29818
Cost B ₁	37342	38800	39082	38408	28518	26524	26413	27152
Cost B ₂	19652	22150	22857	21553	11138	9649	9663	10150
Cost C ₁	36092	38050	38832	37658	25518	25024	25413	25318
Cost C ₂	18402	21400	22607	20803	8138	8149	8663	8317
Cost C ₂ *	18402	21400	22607	20803	8138	8149	8663	8317
Net return cost C₃	13874	16970	18147	16330	3049	3067	3561	3226
Farm business income	39217	41235	42743	41065	30393	29399	29663	29818
Family labour income	19652	22150	22857	21553	11138	9649	9663	10150
Farm investment income	33439	36370	37497	35768	22304	22817	23561	22894

Source: Author's own calculation

5.2.2 Input output Ratio Analysis

The input output analysis was also done on the basis of cost A₁ to cost C₃ for adopters and non-adopters given in table 5.6. In case of adopters overall average of input output ratio varied from 1:2.67 to 1:1.33. It varied from 1:2.60 to 1:1.28 for small farms, 1:2.72 to 1:1.35 for medium farms and 1:2.69 to 1: 1.37 for large farms. In the same way non-adopter's input output ratio varied from 1:2.06 to 1:1.05 for small farms, 1:1.99 to 1:1.06 for medium farms and for large farms it found 1:1.98 to 1:1.06. The overall average of the input output ratio on the basis of various costs varies from 1:2.02 to 1:1.06.

Table 5.6: Benefit : Cost ratio analysis of adopters and non-adopters

N=100

	Adopters				Non-Adopters			
	Small	Medium	Large	Overall Average	Small	Medium	Large	Overall Average
On the basis cost A₁	2.603	2.721	2.688	2.671	2.061	1.994	1.988	2.015
On the basis cost A₂	2.603	2.721	2.688	2.671	2.061	1.994	1.988	2.015
On the basis cost B₁	2.418	2.442	2.389	2.417	1.935	1.817	1.794	1.849
On the basis cost B₂	1.446	1.509	1.515	1.490	1.233	1.196	1.193	1.207
On the basis cost C₁	2.308	2.376	2.368	2.351	1.762	1.737	1.742	1.747
On the basis cost C₂	1.406	1.483	1.507	1.465	1.160	1.160	1.170	1.163
On the basis cost C₂*	1.406	1.483	1.507	1.465	1.160	1.160	1.170	1.163
On the basis cost C₃	1.279	1.348	1.370	1.332	1.054	1.055	1.063	1.058

Source: Author's own calculation

5.3 Relative importance of the various factors influencing adoption of Resource conservation technology

The estimates of Logit model are presented in Table 5.7. The table shows that six variable out of eight variables used in model were found statistically significant at 1 per cent, 5per cent and 10per cent level. Remaining two variables were found to be non-significant. The chi –square value of 0.149 showed that likelihood ratio statistics are highly significant (p<0.0001) suggesting the model has strong explanatory power. The pseudo-R square was 0.689 indicating the explanatory variable explained about

69 per cent of the variation in the choice of adoption of zero till. The model correctly predicts 96 out of 100 (96.1 per cent) observations.

The analysis shows that the age of the farmer / respondent, as expected have a negative and significant impact on the probability of technology adoption. The older the farmers, the lesser the chances of him adopting zero tillage technology. This effect can be explained by fact that young farmers are more aware of the latest technology and have a larger risk taking ability. Odendo et al. (2009) found similar results that age had a positive correlation with traditional practices.

Education level of the household head had a positive and significant effect on choice of adoption of zero till use. An increase in education level of the adopter increased the probability of choosing zero till technology by 20.38 times than non-adopters. Higher education gives farmers the ability to interpret and respond to new information much faster than their counterparts with lower education (Feder et al., 1985).

Table 5.7: Factors influencing zero till adoption in wheat cultivation

Variable	B Coefficient	Wald	Exp(B)	p-value
Age of the farmer	-0.352*	6.99	.703	0.008
Education	3.015**	3.845	20.38	0.050
Household size	-3.095*	6.761	.045	0.009
Gender of household head	0.856	0.050	2.353	0.823
Total farm size	0.040**	5.132	1.040	0.014
Total farm income	0.338***	3.483	1.402	0.053
Off farm income	0.371**	3.924	1.449	0.049
Source of information	1.595	1.043	4.928	0.307
Log likelihood	17.918			
Cox & Snell or Pseudo R ²	0.689			
Hosmer & Lemeshow Chi square	0.149			
Prediction success	96.1 %			

Note: *, **, *** significant at 1 per cent, 5 per cent and 10 per cent level

The effect of household size was found negative but significant. It implied that for an increase in the household size by one member increase the probability of choosing non adoption by 4.5 times more than the adopters. Households with large families may be forced to divert part of the labour force to off-farm activities in an attempt to earn more income in order to ease the consumption pressure imposed by a large family (Tizale, 2007, Yirga, 2007). On the contrary, large household size positively influences adoption of labor intensive agricultural technologies since they have the capacity to relax the labor constraints required during introduction of new technologies (Croppenstedt et al., 2003; Birungi, 2007, Nyangena, 2007; Odendo et al., 2009).

Table 5.7 showed the results of farm size were found to be positive and significant. The choice of adoption of zero till technology was significantly influenced by the size of farm. An increase in farm size by one ha increased the probability of choosing adoption of zero till technique by 1.04 times more than non-adopters. Small land holding hinder the usage of technologies compared to large land holding. A large farm size allows a farmer to experiment new technologies on a portion of land without worrying about compromising the family food security. In addition, the benefits from large-scale adoption of new technologies are higher for larger farms (Zepeda, 1994).

The analysis showed that farm income also had positive and significant effect on the adoption of zero till. The results indicated that with the increase of one thousand rupees in farm income the probability of adopting zero till technology will be increased by 1.40 times .

Results indicated that off-farm incomes reduce the odds of adopting zero till among adopters, by 1.44 times than non-adopters by holding other things constant. A more plausible explanation would be that households' major sources of income are off-farm activities and that they would less likely invest in agricultural technologies. One other explanation would be that non-agricultural incomes may not necessarily be used by farmers to meet capital costs required to implement new agricultural

technologies but rather to acquire other basic needs in their households. Nonetheless, the positive and statistically significant sign on income received as in-kind implies that farm households that receive income as in-kind are more likely to adopt zero till. In case of gender and source of information, the results were found to have positive but non-significant effect for technology adoption.

5.4.1 Assessment of the economic impacts and surplus of zero tillage

The significant farm level impacts of zero till in terms of yield increase and cost savings translate into a downward shift of the supply curve. The aggregate welfare effect of this shift was estimated through the economic surplus approach by using various assumptions and parameters, *ceteris paribus*. The fundamental assumption is that the observed adoption levels would have four years lag, after that the technology was adopted. The estimates of the benefits are conservative in the sense that they only include the welfare effects attributable to the tangible direct benefits. For the more optimistic scenario assume ZT induces 12 per cent yield gains and 10 per cent cost savings which was earlier calculated in second objective i.e. economics of wheat. Based on the information compiled from various sources supply and demand elasticities were taken 0.40 and 0.22, respectively (Vijaylaxmi et al. 2009) with a ceiling level of 25per cent. For the discount rate 5per cent value was imputed and the real prices were calculated 18.87 \$ with the help of real price index.

Table 5.8: Selected parameters for impact calculations

Indicator	Values
Elasticity of demand	0.22
Elasticity of supply	0.40
Social discount rate	5 %
Ceiling level of ZT/RT adoption	25 %
Yield advantage	12 %
Change in per ha cost of cultivation	10 %
Real prices	18.87\$
Timeframe	1997 base year +20 years

Table 5.9: Economic benefit of zero till in Eastern Uttar Pradesh

Year	Producer Benefit	Consumer Benefit	Economic surplus
1997	0	0	0
1998	0	0	0
1999	0	0	0
2000	0	0	0
2001	76.8	139.6	216.4
2002	153.6	279.3	432.9
2003	230.4	419	649.4
2004	307.3	558.6	865.9
2005	384.1	698.3	1082.4
2006	460.9	838	1298.9
2007	537.7	977.7	1515.4
2008	614.6	1117.4	1732
2009	681.4	1257.1	1938.5
2010	768.3	1396.8	2165.1
2011	845.1	1536.6	2381.7
2012	922	1676.3	2598.3
2013	998.8	1816	2814.8
2014	1075.5	1955.8	3031.3
2015	1152.5	2095.5	3248
2016	1229.4	2235.3	3464.7

Note: All the values are calculated in US \$ (US \$1 = Rs. 63.59)

Results of analysis in table 5.8 showed that in the starting years i.e. from the year 1997-2000 the economic surplus was zero because there was an adoption lag. At that time the supply and refinement work was going on. After the year 2000, producers and farmers started adopting the technology and benefit realization started. In the year 2001, the total economic surplus due to the adoption of the technology was calculated as 216.4\$ out of which the producer surplus was 76.8\$ and consumer surplus was 139.6\$. In, 2014 the producer consumer surplus was calculated as 1075.5\$ and 1955.8\$ respectively which was 92 per cent more than the surplus in year 2001. It was estimated that in 2015 the economic surplus will be increased by 6.6 per cent from the last year and in the year 2016 it will be increased by 6.25 per

cent than year 2015. From the results it was concluded that as adoption was increasing the producer and consumer surplus i.e. overall economic surplus was increasing at faster rate. The increase in the consumer surplus was found to be more than the producer surplus, therefore, it is suggested that for overall benefit of the society policy should be framed by incorporating consumer surplus also. It is suggested that government should give more focus on the technology so that both producer and consumers get benefited and economic surplus can be increased.

5.4.2 Assessment of the environmental impacts and benefits of zero tillage

The farmers are using mechanical power for land preparation, sowing, pumping irrigation water, harvesting and threshing for wheat, which increases the use of diesel in farming operations. The reduction in diesel use ultimately affect environment positively. For the estimation of CO₂ emission from wheat crop here only the land preparation and sowing operations were considered and it was assume that for the rest of the activities fossil fuel consumption for mechanical power would be the same in both cases, i.e., conventional and resource conservation agriculture system.

Table 5.10: Environmental benefits of zero till

Land preparation and operations	Adopters	Non-adopters
Sowing	5.5 hour per ha	
Ploughing		8.5 hour per ha
Planking, harrowing, sowing		4.2 hour per ha
Total operation	5.5 hour per ha	12.7 hour per ha
Diesel required	3.35 liter per hour	3.35 liter per hour
Total diesel required	18.425 liter per ha	42.545 liter per ha
CO ₂ Produced	47.905 kg CO ₂	110.62 kg CO ₂
Carbon equivalent	12.93 kg carbon	29.86 kg carbon
Cost of diesel usage	1039.17 Rs./ha	2399.53 Rs./ha
Benefits by saving	Rs. 1360.37 (56.7per cent)	

Source: Author's own calculation

Zero till in wheat crop has several environmental benefits. Zero till implies significant fossil fuel savings and reduced greenhouse gas emissions (Grace et al., 2003; Hobbs and Gupta, 2003). The results of the table 5.10 showed that in case of adopters only sowing was done with simple land preparation operation which takes 5.5 hour per ha and consumes 3.35 liter diesel per hour (in total 18.46 liter diesel per ha), but, on the other hand the non-adopters required more number of operations for the land preparations like ploughing, planking, harrowing and sowing which takes 12.7 hours per ha and 3.35 liter diesel per hour i.e. 42.56 liter diesel per ha.

It was estimated from the results that the total CO₂ emission from the use of zero till by adopters was 47.91 kg which was nearly 63 per cent less than the CO₂ emission produced by the non- adopters i.e. 110.62 kg CO₂ by using their conventional method to produce wheat. The amount of carbon produced by the adopters was 12.93 kg and from the non- adopters was 29.86 kg.

Zero till is not only an environmental friendly technology but also a cost saving technique. The results of the analysis showed that the total cost estimated of diesel per ha for land preparation by adopters was Rs. 1309.17 and for non-adopters was Rs. 2399.53. The difference between the costs of land preparation was Rs. 1360.37 which benefited the adopters by 56.7 per cent more than the non-adopters.

Therefore, it was concluded that zero till technology was a highly beneficial technology in terms of environmental safety and cost saving.



SUMMARY AND CONCLUSIONS

Summary

A brief summary of the present study along with some important policy implications emerged out from the results of the study is presented in this chapter. It was tried that the policy implications suggested would help planners and policy makers to take appropriate policy measures to improve the adoption of zero till in Eastern Uttar Pradesh.

Agriculture in India is the primary occupation and is one of the strongholds of Indian economy from the perspective of poverty alleviation, income and employment generation. The food grain production in India which was 5.16 million tonnes in 1950-51, increased to the level of 251.12 million tonnes during 2014-15 (3rd advance estimates). India is also the second largest producer of wheat in the world with an average annual production of 95.76 million tonnes in year 2014-15*(estimated, Department of Agriculture and Cooperation, 2015). Uttar Pradesh is the largest wheat-growing state in the country with an area of 9.96 million hectares and produces 30.25 million tonnes of wheat with yield level of 30.38 quintal per ha in year 2014-15 (Department of Agriculture and Cooperation, 2015).

From sustainability and profitability point of view, it will be important to conserve the natural resources. In recent years, decline and deterioration of natural resources has emerged as a serious concern for sustainable food production in our country. Optimization of the use of natural resources, inputs and diversification/intensification of cropping system through use of fallow lands/rice fallows are the major issues for conservation agriculture and sustainable agriculture development. Conservation agriculture has come up as a new archetype to achieve goal of sustained agricultural production. It is a major step toward transition to sustainable agriculture.

Globally the total area under conservation agriculture was 45 million hectares in 1999 which increased to 95 million hectares by the year 2005. In 2008, total area under conservation agriculture was 105 million hectares. Out of this, the share of different continents was 49.58, 40.07, 12.16, 2.53, 1.15 and 0.37 million hectares for South America, North America, Australia and New Zealand, Asia, Europe and Africa Respectively (Derpsch and Friedrich, 2009 as cited in Singh et al. 2010). In India, presently more than 2 million hectares area in Indo-Gangetic plains under rice wheat system is under resource conserving technologies (Singh et al. 2010). In Eastern Uttar Pradesh the area under zero till technology was 9510 ha in the year 2003-04, which is increasing at a very slow rate.

Major challenges

Starting from the 1960s, expansion of area and growth of rice–wheat productions system based on the adoption of modern technologies, incorporating the use of high-yielding varieties, fertilizers and irrigation, led to increased production and productivity of both these crops. However, continued intensive use of these technologies in recent years has resulted in lower marginal returns and, in some locations to salinization, overexploitation of groundwater, physical and chemical deterioration of the soil, and pest problems.

There are many approaches to overcome these problems, of which, straw retained on the soil surface reduces weed seed germination and growth, moderates soil temperature and reduces loss of water through evaporation. Despite these potential benefits, however, large quantities of straw (left over after rice and wheat harvesting) are burnt each year by farmers to facilitate land preparation for crop planting. It is estimated that the burning of one ton of straw releases 3 kg particulate matter, 1460 kg CO₂ and 199 kg ash. With the development of new drills, which are able to cut through crop residue, for zero-tillage crop planting, burning of straw can be avoided, which amounts to as much as 10 tons per hectare, potentially reducing release of some 13–14 tons of carbon dioxide (Gupta et al., 2004).

Need of the study

Despite of the fact that resource conservation technologies are proved to be cost reducing, profitable and sustainable on farmers' field and research farms, the demand and diffusion of these technologies are not getting momentum as per the estimation and expectation of the researchers, extension workers and policy makers.

The major challenge to wheat production in the state is the enhancing of its productivity and profitability. Adoption of zero tillage technique is one such step in this direction. As an alternative to the conventional tillage, zero tillage technology uses direct seeding of wheat crop just after harvest of rice with the help of zero-till seed drill without preparatory tillage. Thus, zero-tillage ensures early sowing of wheat and reduces cost of cultivation.

Objectives

1. Elicit and characterize farmer's demand and diffusion for zero till and its forecasting in the rice wheat cropping system.
2. To find out the economics of wheat under RCT.
3. To determine the relative importance of the various factors influencing adoption of Resource conservation technology.
4. To assess the economic and environmental impacts of zero tillage.

Methodology

Multistage stratified purposive sampling was used. All 27 districts of Eastern Uttar Pradesh were arranged according to the adoption level of RCT and Chaundauli district having highest adoption was selected purposively. Twenty per cent blocks (2 blocks) were selected having highest adoption level of zero till. One village having highest adoption level was selected purposively from each block and one adjoining village having low adoption was also selected purposively from each block. Category wise list of farmers was prepared and 10 per cent farmers from each category were

selected randomly, which finally constituted 52 adopters and 48 non-adopters. The study was conducted with the total 100 farmers sample size.

There are different resource conservation technologies like zero till, laser leveler, rotavator etc. Out of them zero till was the only resource conservation technology which was adopted by majority of the farmers of Chandauli, therefore, only zero till was considered for study.

The primary data was collected with help of pretested schedule by personal interview method for the crop year 2013-14. Secondary information was collected from published journal, bulletin and official records of districts and blocks.

For the first objective i.e. to characterize the farmer's demand, diffusion and forecasting willingness to pay method, review was done on the various research papers and different governmental policies and linear trend equation were used' respectively.

The second objective was fulfilled by calculating the cost and returns in wheat production and comparing the net returns per ha in both the categories.

Logit model was used to identify the important factors which influenced the farmers' decision to adopt the zero till technology in Eastern Uttar Pradesh.

For the fourth objective the economic surplus and the environmental benefits of zero till were calculated.

Main findings of the study

1. The perception of the owner of the zero till revealed that when the price increased by 20-30 per cent then still farmers (adopters) were interested to adopt but after that adoption was affected badly.
2. In case of price decrease the exiting owners were remained same but the custom hiring adopters and non-adopters showed interest to purchase the machine and aggregate demand increased from 16 to 58 farmers. A reduction of Rs. 5000 in the existing price of zero till was found to be rational.

3. In India, research on ZT for wheat started almost three decades ago (Ekboir 2002). Several state agricultural universities tried ZT in the 1970s but their efforts failed due to technical difficulties. In the year 1991, first prototype of the Indian ZT seed drill was developed at G. B. Pant University of Agriculture and Technology, Pantnagar. After further refinement the zero till technology in wheat after harvesting of rice was introduced first time during Rabi, by NDUAT, Kumarganj, Faizabad on massive scale in Eastern Uttar Pradesh by covering 550 ha area of 290 farmers belonging to 17 districts. After getting encouraging results, the area which was 1430 ha (2002-03) was increased to 9510 ha (2003-04) due to adoption of technology by 3822 farmers in Eastern U.P.
4. The per annum growth of the sale/supply of zero till was found 6 per cent and showed an increasing trend. The results of forecasting showed that in year 2015, 2016 and 2017 the sale of zero till may be 162,168 and 173 units per year respectively.
5. In case of adopters small farmers are putting more human resources despite the use of resource conservation technology; it is because of availability of family labour, while medium farmers are paying attention on fertilizer use and large farmers are using more irrigation facility but in case of non-adopters there is nominal difference in the pattern of expenses of seed, fertilizer, plant protection chemicals, irrigation and tractor use except human labour. The share of human labour expenditure was found to be higher on small farms, because of availability and use of family labour.
6. Age of the farmer, education level, farm size, household size, off farm income, total farm income showed significant effect on the adoption decision of the farmer.
7. Economic surplus in the starting years i.e. from the year 1997-2000 was zero because there was an adoption lag. In the year 2001, the total economic surplus due to the adoption of the technology was calculated as 216.4\$ out of which the producer surplus was 76.8\$ and consumer surplus was 139.6\$. It was estimated that in 2015 the economic surplus will increased by 6.6 per cent

from the last year and in the year 2016 it will be increased by 6.25% than year 2015.

8. The total CO₂ emission from the use of zero till by adopters was 47.91 kg which was nearly 63% less than the CO₂ emission produced by the non-adopters i.e. 110.62 kg CO₂ by using their conventional method to produce wheat. The amount of carbon produced by the adopters was 12.93 kg and from the non- adopters was 29.86 kg. The cost saving by adopters in comparison to non-adopters, under land preparation was Rs. 1360.37.

Conclusions

1. If the prices of the machinery go beyond the 40% then there won't be any demand of zero till.
2. Being elastic demand, the reduction in price will improve the demand significantly. When price decrease by 20-30% the elasticity demand is highly elastic, therefore it is suggested that a subsidy of Rs. 5000 will have a significant impact on demand of zero till.
3. Farmers had favourable attitude towards zero tillage technology even the non-adopters are convinced about the advantages. The known adopters were also aware of the benefits of zero tillage technology; however, efforts are required to motivate farmers for adoption of zero till through awareness campaign and other dissemination mechanism.
4. There is 6% annual growth in supply/ sale of zero till machine.
5. . Farming community is looking for yield increasing and cost reducing technologies for improving farm profitability. The findings of study have revealed that it is possible to reduce cost (machine labour and seed, fertilizer) under zero tillage as compared to the conventional method by 12% and yield enhancement (timely sowing of wheat, reduction in weed density) by 10% through ZT.
6. Household size, age, education, farm size, non-farm income and farm income of the farmers were the main factors which influenced the decision of the

farmer to adopt zero till technology. Gender, yield and sources of information were found non-significant which implies that they have no relevance with the farmer's decision to adopt a technology or not.

7. Zero till is not only an environmental friendly technology but also a cost saving technique by minimizing the fossil fuel use. The empirical results showed that the CO₂ emission was nearly 63% less than the CO₂ emission produced by the non- adopters by using their conventional method to produce wheat. The cost saving of adopters was found to be 56% more than the non-adopters.
8. It can be concluded that as adoption is increasing the producer and consumer surplus i.e. overall economic surplus is increasing at faster rate. Both the consumers and producers are benefited by the technology adoption.

Policy implications

1. Government and manufacturer should work together to popularize zero till mechanization. From manufacturer side the effort should be made for cost reduction and from government side incentives/subsidy and an effective extension mechanism should be promoted.
2. Since, ZT is used along with tractor; therefore, a mechanism should be adopted by government/manufacturer to promote the sell of zero till at the time of the purchase of the tractor through various incentives.
3. Effective extension mechanism, farmers' training and demonstration for large scale adoption of improved agronomic practices should be promoted and awareness programme should also be taken in to account.
4. While designing subsidy /incentives consumer surplus and environmental benefits should be taken into account.



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SURVEY SCHEDULE

**Department of Agricultural Economics,
Institute of Agricultural Sciences, BHU, Varanasi.**

**Topic: Demand, Diffusion, Economics and Impacts of Resource Conservation
Technologies in Eastern Uttar Pradesh**

Date:

1.0 Location

1.1 Village Block District

2.0 Name of head of family
Age (year)

2.1 Educational status
Farming Experience (Year)

3.0 Occupation

Agriculture	Dairy	Agriculture & Dairy	Service	Business	Others

4.0 Family composition

S. No.	Particulars	Total Family member	Adult		Child		Old	
			M	F	M	F	M	F
1.	Number							
2.	Occupation							
3.	Education							

Illiterate [1]; Primary [2]; Secondary [3]; High school [4]; Intermediate [5]; Graduate [6]; Post graduate [7]; Professional [8]

5.0 Detail of land holding (Bigha)

Total area	Cultivated Area		Irrigated Area	Un-irrigated area	Leased in land	Leased out land
	Rabi					
	kharif					

6.0 Cropping pattern

Kharif		Rabi		Zaid	
Crop	Area (Bigha)	Crop	Area (Bigha)	Crop	Area (Bigha)
Paddy		Wheat		Water melon	
Urd		Barley		Musk melon	
Moong		Gram		Cucumber	
Cowpea		Sunflower		Taroi	
Groundnut		Mustard			
Pigeon pea		Pea			
		Masur			

7.0 Familiarity of Resource Conservation Technologies (RCTs) for wheat

	Zero Till	Other than ZT
Familiar ¹		
Info source ²		
year of 1 st use		

¹ **familiarity:** 0-not familiar; 1-heard about it; 2-seen it in other fields; 3-adopted in own field;

² **main info source types:** 1- govt. extension; 2-cooperatives; 3-NGO; 4 private dealer; 5 –exhibition;6-mass media;

8.0 Details on wheat area and adoption of RCT for 2013-2014 period

Category	Machine used/manual	Conv. till	Zero till
Ploughing			
Harrowing			
Land leveling			
Seeding			
Date of sowing			

9.0 Details on wheat output 2013-14

Category	Yield (Quintal/acr)				
	Zero till	Reduced till	Conven. till	Bed plant.	Surf. Seed.
Yield (Qtl/ha)					

10.0 What did you do with the wheat crop residue last year?

- a) Used for livestock
- b) Left in the field for soil cover
- c) Sold for price (if this is the option, write the money earned/acre: _____ Rs/acre)
- d) Burnt the residue

13. Perception of farmer if price of ZT increases or decreases

Change in the prices of ZT	Increase	Decrease
0%		
10-20%		
20-30%		
30-40%		
40-50%		

14. Details on other crops cultivated during rabi 2013

Crop	Area (acres)	Net income (Rs)

15. Inputs Use (Per Bigha)**15.1 Fertilizer use**

Seed		Manure		Chemical Fertilizer								Insecticide / Pesticide	
Qty	Price / kg	Qty	Price	Nitrogen		DAP		Potash		Others		Qty	Price / Liter
				Qty	Price / bag	Qty	Price / bag	Qty	Price / bag	Qty	Price / bag		

15.2 Source of irrigation water

Groundwater	Surface water

15.3 If groundwater then

Own well / Tubewell	Water Purchase

15.4 Source of energy

Electric pump	Diesel pump	Others (Specific)

15.5 Energy price

Electric charge (Rs. /HP/ Month)	Diesel price (Rs /Liter)	Diesel Pump HP	Diesel consumption (liter/hrs)

15.6 Water Charges (Rs/Hr)

Electric Pump	Diesel Pump	Canal price

16 Labour Use

Ploughing										
No. of Operation	Human Labour						Bullock labour		Tractor / Machine	
	Hired		Family		Rate (Rs/day)		Hours	Rate (Rs/day)	Hours	Rate (Rs/Hr)
	M	F	M	F	M	F				

Manuring						Sowing							
Human Labour						Human Labour						Machine labour	
Hired labour		Family labour		Rate (Rs / day)		Hired labour		Family labour		Rate (Rs / day)		Hrs	Rate (Rs/hrs)
M	F	M	F	M	F	M	F	M	F	M	F		

Fertilizer Application						Irrigation							
Human Labour						No. of Operation	Human Labour						
Hired labour		Family labour		Rate (Rs / day)			Hired labour		Family labour		Rate (Rs / day)		
M	F	M	F	M	F		M	F	M	F	M	F	

Insecticide / Pesticide Application						Harvesting							
Human Labour						Human Labour						Machine labour	
Hired labour		Family labour		Rate (Rs / day)		Hired labour		Family labour		Rate (Rs / day)		Hrs	Rate (Rs/hrs)
M	F	M	F	M	F	M	F	M	F	M	F		

Threshing							
Human Labour						Machine labour	
Hired labour		Family labour		Rate (Rs / day)		Hrs	Rate (Rs/hrs)
M	F	M	F	M	F		

Irrigation			Output			
No. of Irrigation	Hrs / Irrigation	Rate (Rs./ Hrs)	Main Product		By Product	
			Quantity	Price / qtl	Quantity	Price / qtl

17. Fixed Cost (Rs/Year)

Rental Value of Land (in per bigha.)	Land Revenue (in per bigha)