Approaches for Resource Conservation Towards Improving Nutrient Use Efficiency

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Resource conserving approach refers to those practices that conserve resources and ensure their optimal utilization and enhance resource or input use efficiency. Resource conservation approaches like zero and reduced tillage systems, better management of crop residues, planting systems, laser land leveling, site specific nutrient management (SSNM), leaf colour chart (LCC), soil plant analysis development meter (SPAD/chlorophyll meter) green seeker, soil test crop response, fertigation, customized fertilizer and agro-forestry, which enhance conservation of water and nutrients.

Introduction
Indian agriculture is entering a new phase. The major research and development efforts in the green revolution era focussed on enhancing productivity of selected food grains and few other crops. The new challenges demand that efficient resource use and conservation receive high priority to ensure earlier gains can be sustained and further enhanced to meet the emerging needs. Issues of conservation have assumed importance in view of widespread resource degradation problems and the need to reduce production costs, increase profitability and make agriculture more competitive. Over the past three decades or so, internationally, rapid strides have been made to evolve and spread resource conservation approaches like zero and reduced tillage systems, better management of crop residues, planting systems, laser land leveler, site specific nutrient management (SSNM), leaf colour chart (LCC), soil plant analysis development meter (SPAD/chlorophyll meter) green seeker, soil test crop response, fertigation, customized fertilizer and pressurized irrigation, which enhance conservation of water and nutrients. Conservation agriculture (CA) which has its roots in universal principles of providing permanent soil cover (through crop residues, cover crops, and agro-forestry), minimum soil disturbance and crop rotations are now considered the principal road to sustainable agriculture: a way to achieve goals of higher productivity while protecting natural resources and environment. Conservation agriculture is currently practised on more than 80 million ha worldwide in more than 50 countries and the area is expanding rapidly. The conventional mode of agriculture through intensive agricultural practices was successful in achieving goals of production, but simultaneously led to degradation of natural resources. The growing concerns for sustainable agriculture have been seen as a positive response to limits of both low-input, traditional agriculture and intensive modern agriculture relying on high levels of inputs for crop production. Sustainable agriculture relies on practices that help to maintain ecological equilibrium and encourage natural regenerative processes, such as nitrogen fixation, nutrient cycling, soil regeneration, and protection of natural enemies of pest and diseases as well as the targeted use of inputs. Agricultural systems relying on such approaches are not only able to support high
productivity, but also preserve biodiversity and safeguard the environment. Conservation agriculture has come up as a new paradigm to achieve goal of sustained agricultural production. It is a major step toward transition to sustainable agriculture.

**Conservation Agriculture**

Conservation agriculture is a broad term and it encompasses all conserving techniques that conserve resources any way (Picture 1). It also involves following RCTs:

1. Permanent soil cover, particularly through retention of crop residues on the soil surface
2. Sensible, profitable rotation; and
3. A minimum level of soil disturbance, e.g., reduced or zero tillage.

![Picture 1. Three pillars of conservation agriculture.](image)

**Resource Conserving Approach / Resource Conserving Techniques**

Resource conserving approach refers to those practices that conserve resources and ensure their optimal utilization and enhance resource or input use efficiency. These techniques include:

(A) **Tillage and crop establishment**

Laser land leveling, conservation tillage (zero/minimal tillage), bed planting/(FIRBS), ridge and furrow, rotary tillage, stale seed bed, system of rice intensification (SRI), direct seeded rice (DSR), precision farming, use of leaf color chart (LCC), SPAD meter, green seeker.

(B) **Crop management**

Clean crop seed, sowing (date, method & rate), crop/variety, fertilization (N), water management, crop diversification and crop rotation, integrated crop management (ICM)

(C) **Soil solarization, mulching, crop residue management, and brown manuring**

(D) **GMCS/HTCs, deleterious rhizobacteria (DRB), Microbial consortia and allelopathy**

Some important RCTs have been discussed here.

**Laser Land Levelling**

It is a precursor of resource conserving technique and a process of smothering land surface (± 2 cm) from its average elevation using laser equipped dragged buckets. It leveled the surface having 0 to 0.2 % slope so that there is uniform distribution of water may takes place and thus enhances resource use efficiency. Advantages of laser land leveling are as follows about 4% rise in area under cultivation due to removal of bunds and channels, saves 10-15% water due to uniform distribution, increases resource (N, P and K). Precision leveling irrespective of planting technique exerted significant effect on uptake efficiency of N. The uptake efficiency of N under PLRB was significantly higher over all other treatments during both the years. Further, the uptake efficiency under PLFB also improved.
significantly compared to TLRB and TLFB. The uptake efficiency of P was significantly improved with precision leveling compared to traditional leveling irrespective of the planting methods. The uptake efficiency of P between raised beds & flat sowing with precision leveling and that of traditional leveling with raised beds and flat sowing did not varied significantly during either of the years of experimentation. The uptake efficiency of K under precision leveling in either of planting techniques (raised beds and flat sowing) did not varied and was significantly superior to both the planting techniques under traditional leveling.

Zero Tillage
Zero tillage is an extreme form of conservation tillage (CT) in which mechanical soil manipulation is reduced to traffic and sowing only. It helps in paradigm shift in crop production. The current and potential area is 2.0 m ha and 10 m ha under zero tillage in India, respectively. It is very helpful in the area of intensive cultivation where a turn-around period between two crops is really very less and thus it can facilitate timely sowing. Advantages of the zero tillage are as follows saving of fuel and labour cost reduced cost of cultivation, saving approximately Rs. 3000/- ha\(^1\) towards field preparation. Timely planting gave yield advantage approximately 2 q/ha for a week advanced sowing in wheat crop and reduces soil erosion and improves soil health. The residues retention under tillage and no-tillage led to greater N utilization by wheat. Maximum N fertilizer utilization 24.1 %, 62.7 % and 38.0 % in wheat was found under no tillage + residues during 2006, 2007 and 2008 respectively. The average of three year data showed that residue retention significantly enhanced the fertilizer N utilization (38.7%) compared to residue removed treatment. The fertilizer N utilization was slightly increased in tillage (34.4%) than no tillage (32.6%). In over all, the N fertilizer utilization was increased in no tillage + residue treatment (Mohammad et al. 2012)

Rotary Till Drill
This machine is a combination of rotavator, seed- cum- fertilizer drill & light planker- cum-driving wheel at the back. All the operations like sowing, ploughing, incorporation of residues and green manure crops can be perform under single operation by using rotary till drill. Advantages of the rotary till drill are as follows low energy, time and labour requirement, useful to incorporate green manure crop, weeds and residues, simultaneous land preparation and sowing, useful in intercultural operation in horticultural crops and puddling can also be done with single operation only.

Leaf Color Chart and SPAD Meter
Leaf colour chart popularly known as LCC now used in determination of leaf nitrogen content based on chlorophyll content in the leaves at different growth stages. A LCC value of 4 indicates that there is 1.4 to 1.5 mg N / g leaf weight. The critical LCC value for rice hybrids and HYVs is 4 and for and basmati rice is 3. These values have to taken from 7-10 DAS or 20-25 DAT to heading. Suitable SPAD meter values for rice and are 37.5 and for 42. Singh et al. (2008) and Balasubramanian et al. (2003) also reported LCC3 as the critical shade for guiding fertilizer N applications to DSR in the Philippines. Singh et al. (2002) and Shukla et al. (2004) reported LCC4 as the critical shade for applying fertilizer N to transplanted rice in north western India. As agronomic and recovery efficiencies are determined by magnitude of response and quantity of fertilizer N applied, these measures of N-use efficiency were the highest when fertilizer N was applied to DSR following LCC3 as the critical shade (Tables 5and 6). Physiological efficiency, which signifies the translation of N absorbed by plant into grain yield, for the LCC3 guided N management treatment was statistically not different from the highest value recorded in any treatment. These data confirm that need-based N management for DSR following LCC3 as the
critical shade can not only lead to savings in fertilizer N use and high profits but also produce high rice yields and efficient utilization of applied N, which reduces fertilizer N-related pollution problems (Picture 2).

**Picture 2. Leaf color chart and SPAD meter**

**Furrow Irrigated Raised Bed (FIRB) Planting**

Crops sown on 40 cm wide raised beds and irrigation providing in 30 cm wide furrows. Numbers of rows wheat is three; peas, mungbean, soybean, and mustard are two and maize and pigeonpea are one. Wheat after pigeonpea, maize, soybean and peas; and mungbean after mustard and wheat can be sown just by reshaping of beds. Current area under this system is 0.1 m ha. Advantages of the FIRB planting are as follows it promotes crop diversification, saves irrigation water by 25-35 %, saves fertilizer and seed rate up to 25%, it helps in decreasing weed infestation as well as easy weeding, it provide easy passage for drainage of excess water and it facilitates easy rouging in the field crops. Kahlown et al. (2002) conducted an experiment on different method of establishment of wheat and they observed that the NPK levels on RCTs farm ranged from 69 to 72 kg/acre as compared to 81 kg from non-RCTs farm. The efficiency of fertilizer at RCTs farm was greater because of the fact that these allow uniform distribution of the fertilizer, which induces the farmers to use their less quantity. It was especially true in case of zero tillage and laser levelling. Data given in table shows that at the zero tillage and laser levelling farms, fertilizer use efficiency was almost same. In case of zero tillage fertilizers placed close to seed. On precisely levelled farm the distribution of fertilizer is more uniform. Higher fertilizer use efficiency showed that these technologies were more conducive to optimum use of fertilizer. This is followed by bed and furrow, and conventional method of sowing.

**Surface Seeding**

It is a simplest method of zero tillage systems and being promoted in eastern India, Nepal, and Bangladesh. It is mostly suitable in areas where sowing delayed in lowland areas due to excessive soil moisture. The benefits of surface seeding given as no equipment needed for surface seeding, very well suitable for heavy textured soils and it is boon for the areas where land preparation very difficult and costly.

**System of Rice Intensification (SRI)**

SRI method of cultivation produces higher yields with less seed and less water. SRI emphasizes on the need to shift from chemical fertilizers to organic manures. Increased soil aeration and organic matter help in improving soil biology and thus help in better nutrient availability. Pest incidences
are lesser due to increased spacing, thus drastically reducing the need for pesticides. Kumar et al. (2014) conducted a experiment at DRR Farm, Ramachandrapuram on sandy clay loam soil with three varieties and three systems of crop establishment viz., system of rice intensification (SRI), Eco-SRI (nutrients supplied through organics) and standard transplanting (ST) indicated that SRI and ST were on par and significantly superior to ECO-SRI with respect to N, P and K uptake in both the kharif and rabi seasons. Though the nutrients uptake remained the same, nutrient use efficiency was marginally higher in SRI (by 8, 8 and 12% for N, P and K, respectively, during kharif and 5% for N during rabi) compared to ST. The amount of accumulation of nutrients that leads to more vigorous plant growth and higher yields is due to changes in capacities of the plant itself, particularly its root system, found considerably higher concentration of N, P and K in the foliage at late stage, reflecting better uptake of nutrients at later stages in SRI method. Soil analysis data indicated similar available nutrient status in SRI and ST after two seasons of experimentation. Thus, SRI resulted in higher productivity during kharif, similar nutrient uptake and marginally higher nutrient use efficiency without depleting the soil available nutrients compared to standard transplanting, after two seasons.

**Important Features of SRI**
- Low seed requirement (5 kg ha-1)
- Low water requirement (soil sufficiently moist but not continuously flooded, mostly aerobic and not saturated)
- Transplantation of tender/ young seedlings (8-12days)
- Transplanting at wider spacing (10 x 10 inches or 25 x 25 cm)
- Incorporating weeds into the soil while weeding with conoweeder/ rotary hoe
- Organic manures in place of chemical fertilizers
- Pest management without chemicals
- Other beneficial practices get recommended for use with SRI, such as selection of most suitable varieties, good seed selection, seed priming and seedbed solarization (Culman et al., 2005).

**Site Specific Nutrient Management**

“Site-specific nutrient management (SSNM) is the dynamic, field-specific management of nutrients in a particular cropping season to optimize the supply and demand of nutrients according to their differences in cycling through soil-plant systems.” Aims of SSNM are provide a locally-adapted nutrient best management practice tailored to the field- and season-specific needs for a crop, increase in yield, high efficiency of fertilizer use, improve profitability, improve marketable crop quality, reduce input costs and improve environmental stewardship. The largest gap between the SSNM and FFP was recorded in sorghum fodder-wheat (38%), followed by sesamum-wheat (33%), rice-wheat (30%), and groundnut-wheat (28%). The smallest gaps were recorded in maize-wheat (24%), and in pigeon pea-wheat (24%). The increase over SR, ISR, and STLR varied from 14 to 20%, 5 to 8%, and 12 to 18%, respectively. (Gill et al. 2010)

The principles of SSNM
1. Optimal use of existing indigenous nutrient sources, including crop residues and manures;
2. Timely application of fertilizers at optimal rates to meet the deficit between the nutrient needs of a high-yielding crop and the indigenous nutrient supply.

**Soil Test Crop Response Approach**

Soil test is a chemical extraction of a soil sample to estimate nutrient availability. Soil tests extract part of the total nutrient content that is related to (but not equal to) the quantity of plant available

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nutrient. A soil test level represents only an index of nutrient availability. Soil testing is a basic inventory and necessary information has to be built in the system for translation the result of soil test to achieve the crop production goal. Assessment / evaluation of soil fertility, to provide an index of nutrient availability in soil and a basis for development of fertilizer recommendation and to rationalize use of fertilizer more economically & efficiently are the major objectives of soil testing. Four steps of soil testing are, Soil Sampling, Soil Test, Soil test calibration, Fertilizer recommendation. Ideal soil test should be accurate, work on all kind of soils, extract all nutrients simultaneously and cost effective & rapid.

**Green Seeker**

Normalized difference vegetation index (NDVI) measurements made by Green Seeker optical sensor after applying one or two prescriptive doses of N and yield of crop. Calculates NDVI as:

\[
\text{NDVI} = \frac{F_{\text{NIR}} - F_{\text{Red}}}{F_{\text{NIR}} + F_{\text{Red}}}
\]

Where \( F_{\text{NIR}} \) and \( F_{\text{Red}} \) are respectively the fractions of emitted NIR and red radiation reflected back from the sensed area. The sensor outputs NDVI at a rate of ten readings per second. The sensor was passed over the crop at a height of approximately 0.9 m above the crop canopy and oriented so that the 0.6 m sensed width was perpendicular to the row and centered over the row. With advancing stage of growth, sensor height above the ground increased proportionally. Travel velocities were at a slow walking speed of approximately 0.5 ms\(^{-1}\) resulting in NDVI readings averaged over distances of 0.05 m. the benefits are as follow fast and precise optical sensing, reduce crop fertilizer costs, only apply nitrogen to plants that need it, real time variable rate fertilizer application and collect data during existing farming operation. Singh et al. 2011 evaluated vis-à-vis blanket recommendations of 150 kg N ha\(^{-1}\). Application of fertilizer N in two equal split doses half at sowing and half at crown root initiation stage (along with first irrigation) has been found beneficial in increasing grain yield and N uptake of wheat. The removal of N by wheat was generally determined by the total quantity of fertilizer N applied in different treatment plots. High fertilizer N-use efficiency parameters such as recovery efficiency and agronomic efficiency were observed in all those treatments where high yields were recorded by applying moderate amount of fertilizer N at planting and at crown root initiation stages as prescriptive doses and application of need based fertilizer N doses as guided by Green Seeker optical sensor followed (Picture 3).

**Crop Residue Management**

About 400 million tons of crop residues are produced in India alone. In areas where mechanical harvesting is practiced, a large quantity of crop residues are left in the field, which can be recycled for nutrient supply. About 25% of nitrogen (N) and phosphorus (P), 50% of sulfur (S), and 75% of potassium (K) uptake by cereal crops are retained in crop residues, making them valuable nutrient
sources. Unlike removal or burning, incorporation of straw builds up soil organic matter, soil N, and increases the total and available P and K contents of the soil (Picture 4).

**Picture 4. Crop-residue management**

**Brown Manuring**
Brown manuring is a new innovative approach where both rice and Sesbania crops are seeded together. Sesbania is then knocked down by spraying 2, 4-D (0.5 kg/ha) at 25-30 days after sowing. It exerts smothering effect on weed species and is capable of reducing weed population by nearly half without any adverse effect on rice yield. Use of 2, 4-D further enhances the weed suppressive effect as 2, 4-D is effective against sedges and broad leaf weeds. Sesbania surface mulch decomposes very fast to supply N. As a legume, it also fixes atmospheric nitrogen into the soil but is of lesser significance due to shorter of growth period.

**Green Manuring**
Green manuring is the practice of enriching the soil by turning under undecomposed plant material (except crop residues), either in place or brought from a distance. Cover crops, catch crops, and shade crops may, and most commonly are, used for green manuring. A cover crop is one planted for the purpose of covering and protecting the ground during winter. A catch crop is a rapidly growing crop, following a main crop during the same season and occupying the ground for a few weeks only. A shade crop is one used in hot regions to shade the ground during summer and thus prevent heating from rains, excessive heating of the soil, or injury to trees from reflected heat. Green manuring can bring a number of advantages to the grower by adding organic matter to the soil, increasing biological activity, improving soil structure, reduction of erosion, increasing the supply of nutrients available to plants (particularly by adding nitrogen to the system by fixation), reducing leaching losses, suppressing weeds, reducing pest and disease problems, providing supplementary animal forage and drying and warming the soil.

**Table 1: Biomass production and N accumulation of green manure crops as given below**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Age (Days)</th>
<th>Dry matter (t/ha)</th>
<th>N accumulated (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sesbania aculeata</em></td>
<td>60</td>
<td>23.2</td>
<td>133</td>
</tr>
<tr>
<td>Sunnhemp</td>
<td>60</td>
<td>30.6</td>
<td>134</td>
</tr>
<tr>
<td>Cow pea</td>
<td>60</td>
<td>23.2</td>
<td>74</td>
</tr>
<tr>
<td><em>Pillipesara</em></td>
<td>60</td>
<td>25.0</td>
<td>102</td>
</tr>
<tr>
<td>Cluster bean</td>
<td>50</td>
<td>3.2</td>
<td>91</td>
</tr>
<tr>
<td><em>Sesbania rostrata</em></td>
<td>50</td>
<td>5.0</td>
<td>96</td>
</tr>
</tbody>
</table>
Variable Rate Applicator (VRA) / Variable Rate Technology (VRT)
VRT is a component of precision agriculture which provides economic benefits to growers by reducing the application of agrochemicals, including fertilizer, seed and irrigation water. Farmers who can use site-specific management to determine the variability in nutrient needs within individual fields have a unique opportunity to improve their fertilizer use efficiency. To effectively use the new variable-rate technologies, the recommendations should be based upon detailed soil tests, yield maps, and other data sets. If possible, these data should be geographically-referenced using the global positioning system (GPS) to identify the exact location of each data point. Maps showing the variability of each nutrient within the field can be prepared from these data sets, and then used to prepare maps of variability in fertilizer needs across the fields. These are used to develop the database to guide the fertilizer application, adjusting the rates on-the-go, either applying nutrients individually or in combinations of materials. Efficiency is improved because the amount of fertilizer applied is more closely matched to the estimated nutrient requirement for optimum yield for specific areas within the field. Field-average management tends to over-apply nutrients in low-yield areas of the field and under-apply in high yield areas. With site-specific management, rate adjustments are made on the basis of smaller, more uniform areas. Research has shown that one-acre grids are recommended for most intensive grain production areas with a long history of significant fertilization or manuring. Variable-rate application maps are provided to the fertilizer applicator operator to be used in guiding the on-board controller to adjust rates to match the recommendation as the applicator moves across the field. For best results, a database and map of the amounts actually applied should be generated to verify the rates used and to help build a record of the variable-rate applications made in the field. These actual application maps should closely match the recommendation maps.

Table 3. Inputs Saving in Maize by VRA (Griffin et al., 2004).

<table>
<thead>
<tr>
<th>Technology</th>
<th>Percent input saving over Conventional (Fixed) methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRT-N</td>
<td>72</td>
</tr>
<tr>
<td>VRT-P, K</td>
<td>60</td>
</tr>
</tbody>
</table>

Fertigation
In micro-irrigation, fertilizers can be applied through the system with the irrigation water directly to the region where most of the plants roots develop. This process is called fertigation and it is done with the aid of special fertilizer apparatus (injectors) installed at the head control unit of the system, before the filter. The element most commonly applied is nitrogen. However, applications of
phosphorous and potassium are common for vegetables. Fertigation is a necessity in drip irrigation, though not in the other micro-irrigation installations, although it is highly recommended and easily performed.

**Nano Fertilizers**
Encapsulation of fertilizers within a nano particle is one of these new facilities which are done in three ways a) the nutrient can be encapsulated inside nanoporous materials, b) coated with thin polymer film, or c) delivered as particle or emulsions of nano scales dimensions (Rai et al. 2012). In addition, nanofertilizers will combine nano devices in order to synchronize the release of fertilizer-N and -P with their uptake by crops, so preventing undesirable nutrient losses to soil, water and air via direct internalization by crops, and avoiding the interaction of nutrients with soil, microorganisms, water, and air (DeRosa et al. 2010).

**Table 4. Some of advantages related to transformed formulation of conventional fertilizers using Nanotechnology (Cui et al. 2006).**

<table>
<thead>
<tr>
<th>Desirable Properties</th>
<th>Examples of Nano fertilizers-Enabled Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled release formulation</td>
<td>So-called smart fertilizers might become reality through transformed formulation of conventional products using nanotechnology. The Nano structured formulation might permit fertilizer intelligently control the release speed of nutrients to match the uptake pattern of crop.</td>
</tr>
<tr>
<td>Solubility and dispersion for mineral micronutrients</td>
<td>Nano sized formulation of mineral micronutrients may improve solubility and dispersion of insoluble nutrients in soil, reduce soil absorption and fixation and increase the bio-availability.</td>
</tr>
<tr>
<td>Nutrient uptake efficiency</td>
<td>Nano structured formulation might increase fertilizer efficiency and uptake ratio of the soil nutrients in crop production, and save fertilizer resource.</td>
</tr>
<tr>
<td>Effective duration of nutrient release</td>
<td>Nano structured formulation can extend effective duration of nutrient supply of fertilizers into soil</td>
</tr>
<tr>
<td>Loss rate of fertilizer nutrients</td>
<td>Nano structured formulation can reduce loss rate of fertilizer nutrients into soil by leaching.</td>
</tr>
</tbody>
</table>

**Customized Fertilizers**
The Central Fertilizer Committee has included customized fertilizers in the Fertilizer Control Order (FCO) 1985, as a new category of fertilizers that are area/soil/crop specific. Customized fertilizers are multinutrient carriers facilitating the application of the complete range of plant nutrients in right proportion to suit the specific requirements of a crop during its stages of growth. The FCO recognizes customized fertilizers importance and defined as: Multi-nutrient carriers designed to contain macro, secondary and/or micronutrient both from inorganic sources and/or organic sources, manufactured through a systematic process of granulation, satisfying the crop’s nutritional needs, specific to its site, soil and stage validated by a scientific crop model, capability developed by an accredited fertilizer manufacturing/marketing company.
Conclusion

Resource conserving approach should form an important component of the regional strategy for food security, rural development, enhanced profitability, improved environmental quality and sustainability of natural resources. Resource conservation approach like zero and reduced tillage systems, better management of crop residues and planting systems enhance conservation of water and nutrients. Adoption of resource conservation approach leads to sustainable improvements in crop productivity, soil health, and nutrient and water use efficiency. Resource conservation approaches reduce cost of cultivation by considerable saving in labour, diesel, time, fertilizers, pesticides and farm power and also reduce environmental pollution. Resource conserving approaches is more effective in combinations rather than their individual application. Among various RCTs research work are mostly available on tillage practices, mulching, LCC etc. Laser land leveling and rotary tillage, although seem to be potential technologies, information of research work carried out on these aspects are only meagerly available. LCC reduced N requirement approximately 25% of applied N. Zero-tillage is more responsive to applied N as compared to CT in coarse textured soils and increases NUE. Retention of residues increases nutrient uptake and thereby increases NUE in different cropping systems. Actual and potential denitrification rates are high in no tillage in high rainfall area due to creation of anaerobic condition here N is broadcasted and injection method is not practiced. In humid environment and with finer textured oil potential loss with surface residue appears to be minimized by fertilizer management.

References


