Conservation Agriculture in Egypt

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Acknowledgement

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Foreword

The present manual on Conservation Agriculture (CA) is the experience of the Technical Cooperation Project "TCP/EGY/3201 *Rice Straw Management and Conservation of Environment*", which was financed by FAO from 2006 – 2008 and implemented in Egypt together with the MOA. This manual describes experiences and first results of introducing Conservation Agriculture (CA) practices in the major rice cropping system of the Nile delta. The project was to demonstrate the validity of CA under the given agro-ecological conditions aiming at preventing serious environmental hazards such as large-scale rice straw burning after harvest and improving the land productivity on a sustainable basis. The manual is not a scientific paper but presents some useful lessons learned which are worth sharing with a wider public.

FAO's assistance was delivered largely by working with national institutions, both research (ARC) and extension, and with farmers, both small and large, adding value to their resources and activities. This was achieved through on-farm testing of a set of fundamentally new principles and elements in their farming practices, widely known as Conservation Agriculture (CA), for integrated crop-livestock production intensification and for the protection of the environment.

Optimal CA systems are based on at least three practices: i) minimum or no-tillage, ii) permanent cover of the soil with organic matter provided by food crops, residues of previous crops and cover crops and iii) diversified crop rotations, which preferably include N-fixing legumes in the sequence.

Current evidence worldwide shows that the introduction of CA technologies and practices offer enormous potential to simultaneously enhance land productivity, soil health/fertility, farm income and environmental protection. Under similar cropping and management systems (irrigated rice-wheat system) like those in the Nile delta, there is widespread evidence of successful introduction and extension of CA practices in Central, South and East Asia. The fact that CA is now practiced on some 120 million hectares worldwide implies that farmers have accepted CA as a new production system for sustainable agricultural intensification and the protection of the environment.

The positive outcomes of CA offer a real promise and an opportunity for bringing about a sustainable impact on a larger scale on agricultural productivity, livelihoods on an environmentally friendly basis in the Nile delta, which is Egypt's bread basket. This manual describes the successful achievements of on-farm testing and demonstration of the main CA practices and the opportunity for a greater change that now exists.

Acronyms

CA	Conservation Agriculture
Fed	feddan (1 feddan = 0.42 ha)
GOE	Government of Egypt
L.E.	Egyptian pound
MOA	Ministry of Agriculture
SOM	Soil organic matter

Background

Agriculture in Egypt

Egypt's arable area totals about 3.3 million hectares about one-quarter of which is land reclaimed from the desert. About 90 percent of the agricultural area is concentrated in the Nile delta, and the rest falls within a narrow ribbon along the Nile between Aswan (Upper Egypt) and Cairo.
Even though only 3% of the land is arable, it is extremely productive and can be cropped two or even three times per year. Most land is cropped at least twice a year, but agricultural productivity is limited by salinity, which afflicts an estimated 35% of cultivated land, and drainage problems. The country falls within arid and hyperarid zones and thus irrigation from its single river Nile plays a major role.
After wheat, rice is the second priority cereal crop and occupies about 600 thousand hectares or about 22% of the cultivated area in Egypt during the summer season. Approximately 95% of all rice is grown in the six governorates that constitute the northern part of the Nile delta. Rice consumes about 10 billion m3 of water or about 18% of the total water resources in the early 2000. It is expected to fall significantly due to the dissemination of short duration varieties. Rice farming engages about one million families or 10% of Egypt's population.
Because of fertile soils in the Nile Delta, high intensity of sunlight, few diseases and pests, warm weather, good irrigation systems, efficient public research & extension institutions and liberalized pricing/marketing policies rice yields in Egypt are among the world's highest. At 10 tons/ha Egyptian national average rice yield is more than three times the world average (3 tons/ha). Rice is an important export crop and some 1 million tons are exported annually.

Environmental impact of current production practices

It has been estimated that more than 50% of the 3-5 million tones of rice straw residues, which are produced annually by farmers, are burnt in the field as a practical means of disposal. This allows farmers to clear and cultivate land early (within some 1-2 weeks after harvest) for sowing berseem, which is the following major crop. The opportunities available for the use of residues in increasing farm income and value added to the national income have not generally been appreciated. The rice straw burning has resulted in a considerable loss of value to farmers and created extensive air

pollution (viz. “black cloud”) that affects wide areas of the Nile delta and even Cairo (Figure 1).

Figure 1
Burning of rice straw

So far extension and R&D efforts aimed at encouraging rice growers to use rice residues for composting and to treat straw with urea or ammonia thereby increasing its digestibility as feed for ruminants. However, adoption of these practices by farmers was limited and mainly restricted to larger farmers. Also opportunities for off-farm industrial use have largely been ignored. As a result only an estimated 20% of the total annual rice residue output is utilized both on and off-farm.

FAO project: Rice straw management and conservation of environment

Rationale and project implementation

The project *TCP/EGY/3102, Rice straw management and conservation of environment* established a participatory approach for testing the introduction of new concepts and technologies into the existing cereal-berseem-based smallholder farming system. The immediate objectives of the project were:

- To introduce Conservation Agriculture as a production system to solve the bulk of the rice burning problem by leaving the residues in the field and adopting zero tillage technologies and direct seeding
- To make stakeholders aware of the advantages of CA-based production systems
- To introduce CA equipment for mechanized crop planting
- To demonstrate CA-based crop and land management practices
- To integrate Conservation Agriculture practices as a means to improve and optimize crop-soil fertility management for sustainable production intensification,
- To train local specialists, village-level technicians and farmers to enable them to adopt key CA-techniques of straw management, and also to increase their awareness of the harmful effects of the improper treatment of surplus straw.

Technical assistance was delivered through a participatory approach by working jointly with national institutions (Agricultural Research Center-ARC and the Rice Research and Training Center-RRTC), the national extension service and farmers in order to efficiently test the new CA concepts at farmer level.

Testing of CA technology was performed on demonstration fields at farmer level with a total of 10-20 fields for the summer crop (short duration rice) and <10 fields for the winter crops (berseem, wheat) in the main four rice-growing governorates (Kafr-El-Sheikh, Dakahlia, Sharkia, Gharbia) in the northern half of the Nile delta. Each participating farmer was managing one field for testing the main planting methods (broadcasting, manual transplanting and direct seeding) both under traditional tillage regime and under no-tillage. CA fields were treated like the conventional fields in terms of fertilizers, crop variety, seeding rate etc. Crop performance was recorded and soil samples from demonstration fields analyzed on main nutrients and

organic matter. For direct seeding the project had provided three sets of seeding equipment from Brazil, particularly suited for grain crops and one seeder from India.
Key stakeholders for the project were smallholders, who constitute the large majority of all farmers in the delta. Since pharaonic times these farmers are known to be very dynamic and for having developed a very efficient production system.

The crop production system in the Nile delta
Farmers' livelihood in the Nile delta is dependent on a series of major crops such as rice, maize, and cotton in summer and wheat, berseem (clover) and minor crops such as sugar beet, flax, onion, fava bean in winter. Rice and wheat are the most important crops both for home consumption and for the market. Berseem is of particular importance to the farming system as animal feed but also as a crop which sustains the cropping system and the fertility and health of the soil. The predominant cropping systems in the delta area are i) rice-berseem (short duration)-wheat, and ii) rice –berseem (long duration). Since rice is a major component in both systems they were selected for testing CA practices on farmers' fields.
The farming systems in the delta are almost all integrated crop-livestock production system. Virtually every farmer owns livestock mostly one buffalo and sometimes some sheep or goats. Buffalos are mostly used for milk production sometimes also for meat by larger farmers, but they are never used as draft animals. Main means of on-farm transport is the donkey and since the last decades increasingly the tractor. For the maintenance of livestock the farmer has several sources of feed. The principal ones are wheat straw, berseem and to a limited extent rice straw. Both wheat straw and berseem are valuable feed for ruminants and are entirely used for this purpose. Therefore no wheat straw is burnt in the field.
Rice straw is of low digestibility because of its high content in lingo-cellulose and silica and its low nutritive value both in terms of energy and protein. Therefore it is of limited use in animal nutrition. However, shortage of animal feed in the dry season is a general problem and farmers traditionally use rice straw mixed with fresh berseem as a common feed. The total amount of rice straw being used for feed is relatively small and does not exceed 20%. To increase the nutritive value of rice straw the project proposed several techniques i) silage making, ii) treatment with ammonia, iii) treatment with urea, and iv) supplementation with molasses.
Farmers consider rice straw important during the feed shortage in summer but they also regard it as a problem in terms of disposal. For them burning of

rice straw is the easiest way of clearing the field from rice residues and preparing it fast for the next crop. They are not aware of the opportunities which rice residue offer for sustainable increase of land productivity, income and environmental protection within the context of Conservation Agriculture.

In the Nile delta it is standard practice to plow or harrow the fields several times followed mostly by dry leveling in preparation for the subsequent rice planting and irrigation. Some farmers use their own tractor for this purpose but most hire it from neighbors or public hire services. In any case this type of labor involves a considerable cash outlay for farmers. CA technology offers the opportunity to eliminate soil movement entirely, which would translate into substantial cost savings and increased land productivity for the farmer.

There are two major rice planting technique currently in use i) manual transplanting seedlings and ii) broadcasting pre-germinated seed. The latter technique has been increasingly adopted in recent times by many farmers (30%) because transplanting is labor-intensive and labor is scarce and costly. The introduction of mechanized direct (no-tillage) seeding, which is labor and cost saving, has great potential. Berseem is traditionally broadcast into rice stubble directly after the rice harvest, and wheat is broadcast after short duration berseem or rice into cultivated fields in November/December. Also in these cases CA can eliminate soil movement and lead to substantial cost savings.

An alternative seeding technique provided by CA is direct seeding with special seeding equipment. Grain seeds are sown through the residue layer, which remains in the field after harvest, into the soil without any prior cultivation. At present most of the rice, wheat and berseem is harvested manually with the sickle. However, increasingly small-scale combine harvesters are hired by farmers to harvest rice and wheat (Figure 2).

Figure 2
Small-scale combine harvester

Field Work : Technological Achievements of the Project

Conservation Agriculture Technologies

The implementation of no-tillage technologies under CA requires specific equipment, which was provided by the project. Equipment from Brazil and India was introduced because these countries have an extensive experience in CA and are able to provide cost-effective equipment.

The seeders delivered by the project were:

- Tractor-mounted no-tillage (direct) seeders for rice, wheat and berseem: 3 Vence Tudo SA 11500 from Brazil (Figure 3)
- 1 Happy Seeder from India.

Figure 3
Tractor-mounted direct seeder sowing wheat into rice residue

The Brazilian seeders were successfully used under moist and dry soil conditions for direct seeding both rice and wheat. However, it proved less suitable for sowing fine-seeded berseem into rice residue under smallholder conditions. This was mainly due to the specific harvest technology employed by small farmers. More details on this issue are presented below in the chapter: Crop management, Winter crops: Berseem demo fields on small farms.
The Happy Seeder did not perform well for Berseem because the fixed furrow openers did not allow for a depth adjustment accurate enough for this extremely small seed. Depth adjustment in general was difficult and the use of the seeder required experience and operating skills.

Crop management
Summer crop: Rice demo fields.
In 2007 only transplanting and broadcasting were tested under conventional and no-tillage practices. Rice was not direct seeded because the Brazilian equipment arrived too late (September). Transplanting takes place in April-early May some 3-4 weeks earlier than broadcasting. For this purpose nurseries usually are planted in March-April and seedlings are transplanted some 3-4 weeks later. Early planting of rice is important for farmers because

it leads to earlier harvest and early planting of subsequent berseem. Early planted berseem has a longer growth period, which translates into higher yields and more cuts (3-4). The rice varieties vary from farmer to farmer, however, they are all high yielding, early maturing and of short stature. Table 1 and 2 contain yield data from the summer season 2007 and 2008. It is important to note that in both years yields under CA are almost equal to conventional practice without any statistically significant difference. Also yields between planting methods (direct seeding, transplanting, broad casting) show similar yields. This result explains why increasingly farmers abandon labor and cost intensive transplanting for the more cost-effective broadcasting.

Yields were measured with a random sampling method using a 10 m2 frame and also reported yields (in 2008) were collected from farmers. The rice yield is about 10 t/ha, reflecting the average yield of the main rice growing governorates in the Nile delta. Harvest index could be calculated during the 2007-season, it reached 0.47 for no-till rice and 0.44 for conventional rice. This reflects the index of modern grain crop cultivars which are intensively cultivated.

Yield variations between farmers across different planting methods showed higher variability and might reflect the potential of different varieties, and locations. The most important fact, however, is that no-tillage and direct seeding have the same yield potential as the conventional practices. This is evident from Figure 4, which shows no-tillage and conventional rice stands.

Table 1 Rice yield (biomass, grain, straw) (t/fed) of demonstration fields for different tillage and planting methods in summer season- 2007

Locations/ Average	Planting Methods	No-tillage			Conventional tillage		
		Yield (t/fed)			Yield (t/fed)		
		Bio mass	Grain	Straw	Bio mass	Grain	Straw
EL.Hamera	Transplanting	9.70	4.40	5.30	9.92	4.42	5.50
Eshaaka	Transplanting	9.90	3.90	6.00	10.68	4.18	6.50
Shobra Sendy	Transplanting	10.47	5.17	5.30	11.27	5.27	6.00
EL- Malikin	Transplanting	8.88	4.28	4.60	9.38	4.38	5.00
N. EL – Bassal	Transplanting	9.40	4.40	5.00	10.50	4.50	6.00
Bander Basion	Transplanting	10.25	5.25	6.00	10.60	4.80	5.80
Average		9.77	4. 57	5.37	10.39	4.50	5.63
EL. Raghama	Broadcasting	7.60	3.50	4.10	8.06	3.56	4.50
Koom EL- Hagna	Broadcasting	9.21	4.21	5.00	9.98	4.48	5.50
Mitt Azoon	Broadcasting	10.62	5.12	5.50	11.07	5.07	6.00
Senbellaween – B.	Broadcasting	9.28	4.28	5.00	10.51	4.51	6.00
EL – Nashra	Broadcasting	9.52	4.42	5.10	9.82	4.32	5.50
Belkas 2	Broadcasting	9.00	4.20	4.80	9.28	4.28	5.00
EL- Seds	Broadcasting	9.17	4.17	5.00	9.83	4.33	5.50
Samanod- B.	Broadcasting	10.96	4.96	6.00	11.49	5.29	6.20
Average		9.42	4.39	5.06	10.01	4.48	6.23

Table 2 Average rice grain yield (t/fed) for demonstration fields under different planting methods – summer season, 2008

Location	Planting Methods	Grain yield t/fed			
		Samples		Reported	
		No-Tillage	Tillage	No-Tillage	Tillage
El-Hamrawy	Direct seed	5.00	5.00	4.80	5.00
El-Beshma	Direct seed	4.50	4.70	4.00	4.20
El-Sods	Direct seed	4.30	4.00	4.00	3.80
B.El-Hegara	Direct seed	5.25	5.08	4.55	4.50
Average		**4.76**	**4.70**	**4.33**	**4.38**
K.Matboul	Transplanting	4.53	4.00	4.15	3.50
El-Taifa	Transplanting	4.52	4.70	4.00	4.20
Shbra Shendy	Transplanting	4.00	4.25	4.00	4.15
A.Karameet	Transplanting	4.25	4.50	4.15	4.25
El-Danabeek	Transplanting	4.00	4.25	3.50	4.00
El-Hamam	Transplanting	5.17	501	4.90	4.75
Salamon	Transplanting	4.63	4.45	4.20	4.15
Average		**4.44**	**4.45**	**4.13**	**4.14**
El-Reyad	Mechanical	4.40	4.51	4.00	4.20
	Transplanting	-	-	-	-
El-Nashra	Broadcasting	4.87	4.89	4.50	4.70
El-shawamy	Broadcasting	4.93	4.89	4.60	4.50
EL. Hasana	Broadcasting	4.00	4.75	3.70	4.45
El-Sods	Broadcasting	4.15	4.50	3.80	4.20
Mogoul	Broadcasting	4.50	4.30	4.15	4.00
Average		**4.49**	**4.67**	**4.15**	**4.37**

Figure 4
Conventional rice (left) and no-tillage rice (right)

Apart from these yield benefits the cultivation of rice under CA showed some other very important benefits. Both consumption of irrigation water and weed infestation were noticeably less under CA than under conventional production. Unfortunately these parameters were not measured but farmers and extension officers clearly observed this development.

The reason for both occurrences is interconnected and probably related to the soil density. Since the early development of CA it has been observed and measured that the soil under CA increases its bulk density. This is due to fact that the soil is no longer tilled and that it resumes its natural bulk density, which is higher than under tilled condition. Also the soil structure changes and reverts to a status where the structure is no longer determined by tillage but by its original biological processes and the soils inherent life (e.g. organic matter, humus, insects, fungi, earth worms etc.). Contrary to the artificial soil structure of the conventional cultivation, which needs to be renewed by cultivation every season, the soil structure under CA is very

stable due to no-tillage. As a result, under CA irrigation water infiltrated more slowly into the soil profile and the water was retained for a longer time at the soil surface. Farmers therefore needed to irrigate less and saved water. This appears to be very specific to the soil conditions in the Nile delta because it contradicts the general experience elsewhere of higher infiltration rates under CA. These water savings also have a great macroeconomic importance because there is a serious water shortage in the delta and therefore the MOA wants to reduce the acreage under irrigated rice with high water consumption in favor of other less water consuming crops (e.g. maize, cotton).
The longer water retention at the soil surface of CA fields has also a very beneficial side effect on the development of weeds. Weed germination and development is reduced by the irrigation water retained for a longer time on the soil surface.

Winter crops: Berseem demo fields on large farms

Traditionally berseem is broadcast after the rice harvest in September on to the field where residues have been burned or removed. It is either grown as a short duration crop (catch crop) with one cut only until the planting of wheat in November or as a long duration crop with 3 cuts until the next planting of rice in May the following year.
The berseem demonstration fields showed that rice harvesting practices of farmers have a strong influence on the effectiveness of the subsequent no-tillage seeding of berseem. There a considerable difference between the harvesting technology of larger individual farmers/state farms and small holders.
Large farms usually combine harvest the rice crop with large drum type combines, allowing to cut the rice with high stubble. This practice does not reduce the total amount of rice residue in the field, however, it diminishes the part of the rice straw, which **lies** on the ground. Further the drum threshers (e.g. Claas) thresh the entire rice straw. As a result the rice straw is broken and lies without order loose on top of the stubble (Figure 5) where is should ideally be spread evenly to facilitate seeding. Also the large farms often allow herders to graze their animals (livestock, sheep, goat) on their fields after rice harvest. This practice reduces by some 20 to 30% the residue cover on the field (Figure 6). These harvesting practices (drum threshing, high stubble, grazing) facilitated subsequent direct seeding of berseem through the rough rice residue and lead to good crop development and productivity (Figure 7).

Figure 5
Combine harvest (drum thresher) of rice with high stubble on large farm

Figure 6
Livestock grazing rice residues on large farm

Figure 7
Berseem direct seeded into rice residue on state farm

Although the project carried out berseem demonstrations on both smallholdings and some large-scale state farms crop measurements were not made at large scale level. However, observations of the development of berseem, which was direct seeded with the Brazilian seeder into rice residue on the state farms showed that CA-berseem developed and yielded noticeably better than the direct seeded berseem on small farms.

Winter crops: Berseem demo fields on small farms
Harvesting techniques of small holders differ from those on large farms. The majority of small farmers harvest the rice crop manually and thresh it with a stationary thresher on the field. They use rice straw as roughage mixed with berseem for their animals. The amount of rice straw used in this way is limited and probably does not exceed 20%. Increasingly small-size combine harvesters (e.g. Kubota, see Figure 2) adapted to the small field size are being used. This type of harvester was also used on the demo fields. They are head threshers, which only thresh the rice heads and lay down the rice straw on the ground in a thick swath. They also oblige to cut the rice closely to the ground since the thresher requires a minimum length of straw length

to pass the crop through the machine. Grazing of livestock is also not common on small farmers' fields.
As a result the entire residue is lying in dense lines of thick long rice straw on the field (Figure 8).

Figure 8
Rice straw harvested with small size combine on small farm

The thick swathes of rice straw created a considerable problem for the subsequent direct seeding of the fine berseem seeds through the residue. Berseem development of the first cut was very variable because the seedlings hardly managed to penetrate the very thick and dense lines of straw (Figure 9).
The direct seeded berseem showed germination and emergence, which was delayed by some 15-20 days. Therefore also the first cut was delayed compared with the conventional berseem.

Figure 9
Berseem direct seeded into rice residue (small farm)

In Table 3 data on fresh forage yield of berseem and number of cuts are presented. All involved small-scale demonstration farmers had three cuts of the long-duration berseem, which grows from September (rice harvest) to May (planting of next rice crop). There is a clear difference between the number of days to the various cuts and the fresh forage yields between CA demonstration and conventional practice. Compared with the conventional method CA required on average some 15 to 20 days more to reach the cutting stages and the total yield was some 18% lower. This, however, was a result of the wrong harvest and straw handling techniques, having cut extremely low stubble and not having loosened or spread the straw cover evenly, leading to poor, delayed and uneven germination.

Table 3: Fresh forage yield and days to cuts in the berseem demo (no-till) and control fields, season 2007 – 2008

Location	Fresh forage yield (t/fed.) and no of days to cuts												Total yield	
	First cut				Second cut				Third cut					
	Demonstration		Control		Demo.		Control		Demo.		Control			
	Yield	#days	Yield	#days	Yield	#days	Yield	#days	Yield	#days	Yield	#days	Demo.	Control
El-Raghma	9.40	82	13.0	67	13.0	142	16.2	127	18.6	192	19.6	177	41.0	48.8
El-Tarzy	10.00	72	12.4	50	13.4	135	14.6	110	16.3	195	17.0	180	39.7	44.0
Rewina	8.6	77	12.5	59	12.5	142	14.0	124	14.0	202	16.5	184	35.1	43.0
Nemra El-Basal	6.5	98	12.0	83	9.5	158	13.0	143	12.0	208	14.0	193	28.0	39.0

Winter crops: Wheat demo fields 2007/2008

Wheat is usually seeded in November, two to three months after rice. But sometimes it is seeded after short-duration beseem, which is grown between September and November.

Table 4 presents the seed rate of wheat and the amount of rice residues, which remained in the field during wheat sowing since the rice harvest. The residue data are of particular interest because they show how much rice straw is decomposing between rice harvest and wheat sowing during some 2-3 months. Assuming an average rice residue yield at harvest of 5.3 t/fed the decomposition rate at the El-Bashmma farm was 13% and at El-Sods) 25%. The third wheat farm (El-Hamrawy) represents a state farm and here the residue was reduced by some 47%. This, however, is not only due to the natural decomposition of straw but also due to the grazing of harvested fields by livestock herders.

Table 4 Wheat: seed/germination rate and amount of residue

Location	Crop	Seed rate (kg/fed)	Rice straw (t/fed)
El-Bashmma	Wheat	60	4.5
El-Sods	Wheat	60	4.0
El-Hamrawy	Wheat	50	2.8

Generally wheat direct seeded after rice into the residue developed very well on both small farms (Figure 10) and large ones (Figure 11).

Plate 10
Wheat direct seeded into rice residue (small farm)

Figure 11
Wheat direct seeded into rice residue (large farm)

This is also evidenced by Table 5 where yield data, either sampled by extension agents or reported by farmers, are presented. Average sampled yield under no-tillage (CA) was 2.2 t/fed and that under tillage (conventional farming) was 2.3 t/fed. Similar to the rice yields wheat yields under CA reached the same yield level as the conventional production right from the start.

Table 5 Wheat grain yield for demonstration fields , 2008

Location	Grain yield (t/fed)			
	Samples		Reported	
	No. Tillage	Tillage	No. Tillage	Tillage
El-Beshma	2.13	2.25	2.03	2.12
El- Hamrawy	2.27	2.25	2.10	2.15
EL-Sods	2.33	2.40	2.21	2.20
Average	2.24	2.38	2.11	2.16

Field observations revealed that CA demo fields were less infested by weeds than conventionally prepared fields. Unfortunately these observations could not be substantiated by field measurements. Similar to the rice demonstrations lower weed infestation in wheat is probably due to longer irrigation water retention on the soil surface and the fact that with no-tillage the weed bank remains located deep in the soil and weeds cannot germinate. Also the rice residue, which covers the soil after harvest, did not allow weeds to develop freely.

Rice residue and soil fertility

The major concerns of the agricultural research and local farming community regarding rice straw incorporation into the soil are related to the belief

- that crop yields will be reduced
- that rice straw will interfere with tillage operations
- that farmers will not be able to consistently incorporate large amounts of residue in a timely manner
- that added costs for residue incorporation will be incurred.

For these reasons, burning is currently regarded as the only feasible alternative for most farmers to get rid of the rice straw in a fast and low cost manner. The widespread belief that straw application to the soil will reduce yields of the following crop results from the observation of poor crop growth in areas where large amounts of rice residues have accumulated after threshing. Nitrogen immobilization occurs when straw is incorporated into the soil as the material decomposes since the C:N ratio of the rice straw is very high (30 – 100). The decomposition of unchopped rice straw is slow due to the silica in the wax on the surface of the plant material. The waxy plant surface prevents access by microbes. If the straw is chopped microbes can degrade the straw more rapidly.

A high C:N ratio results in utilization of N compounds by microbes for the decomposition of organic material, which therefore are taken away from the current crop. Excess C-compounds are then slowly further converted to CO2 and at that time microorganisms die off and release nitrogen, which may be used for new cell synthesis. In the course of this process the C:N ratio continuously decreases.

The major rice-based cropping systems in the Nile delta almost always comprise berseem, which is an N-fixing legume. Since berseem is usually seeded after rice, the crop has a considerable impact on the decomposition of straw residues.

The organic matter content of the Nile delta soils is low and ranges between 1 to 2%. This is mainly due to the high temperatures, dry climate combined with irrigation, intensive soil tillage and shortage of organic fertilizers and green manures. Furthermore continuous application of agrochemical fertilizers led to environmental pollution in soil
and water. So the only solution to maintain soil fertility is the incorporation of organic material either as residue (rice) or in the form of compost. Since

compost has only a limited potential as a source of organic material (production is too costly for small holders) rice residue is the most accessible other alternative.
The benefits of organic matter on/in the soil, besides improving the physical structure of the soil, are:

- To attenuate extremes in soil temperature, keeping it cooler in summer and warmer in winter
- To utilize rainfall or irrigation water more efficiently, because less moisture is lost due to evaporation and runoff by permitting better infiltration
- To add a bank of biological activity to the soil, which contributes to more efficient nutrient uptake
- To increase the buffering capacity (resist change in pH)
- To increase cation exchange capacity, which allows to hold plant nutrients for a longer period of time, and
- To improve soil structure.

During the first summer season 2007 undisturbed soil samples were collected before land preparation for rice from 0-15 and 15-30 cm depth on the 15 demo fields. The collected samples were subjected to chemical analysis using the standard method of analysis at the Rice Research and Training Center, Sakha, Kafr El-Sheikh.
The results of the chemical analysis from Kootor District, Gharbia governorate, are shown in Table 6 representing a typical delta soil in the main rice growing area. The soil chemical data reveal that the demonstration fields are not salt effected, very rich in phosphorus (> 15 ppm) and rich in potassium (>400 ppm). The pH is high as they generally are in most Egyptian soils. However, after flooding the pH tends to move toward neutral due to the decomposition of organic material and the accumulation of CO_2 and carbonic acid.

Table 6 Soil chemical data collected in Kafr El-Sheikh

Previous Crop	Depth cm	EC ds/m	pH	P ppm	K ppm	Zn ppm	Mn ppm
Sugar beet	0-15	1.01	8.00	14	470	1.64	575
Sugar beet	15-30	1.18	8.15	16	449	1.55	924
Clover	0-15	1.21	8.25	17	400	1.74	497
Clover	15-30	1.09	8.09	16	442	1.62	575
Wheat	0-15	1.23	8.12	17	421	1.53	622
Wheat	15-30	1.11	8.09	16	400	1.29	5.98

Soil samples were also taken after harvest in order to compare the results of chemical analysis before and after rice crop and between CA (no-tillage) and conventional cultivation. Data from three selected governorates are presented in Table 7 and show that major soil parameters under CA are not significantly different from conventional cultivation except K, which tended to increase under no-tillage.

Table 7 Soil chemical analysis (0–30 cm) as affected by tillage practices

Treatment	OM (%)	EC (ds/m)	pH	P (ppm)	K (ppm)
Gharbia Governorate					
No-tillage	1.68	1.21	8.11	17.9	275.5
Tillage	1.91	0.89	8.16	19.8	180.0
Dakahlia Governorate					
No-tillage	1.41	1.50	8.01	16.0	208
Tillage	1.49	0.97	8.10	21.2	300
Sharkia Governorate					
No-tillage	2.35	1.33	8.23	22.10	465.0
Tillage	2.40	1.00	8.10	18.70	256.5

Economic analysis of Conservation Agriculture

The specific objective of the socio-economic component of the project was to conduct financial feasibility analysis of the CA technology in terms of yields, costs and net returns in comparison to the conventional tillage technique. Cost and benefit analysis techniques were employed to assess the financial impact of the proposed technologies in order to determine their financial viability and to allow a comparison with traditional technologies. The analysis considered only incremental costs and benefits and did not consider additional investments and fixed costs.

For the economic evaluation of demonstration fields all cost and benefit items were collected from each participating farmer regarding both conventional tillage and CA (no-tillage). Table 9 shows the main results of the cost-benefit analysis for rice in 2007:

- Rice could be produced under CA with significantly lower costs (15% representing some LE 240/fed) compared with conventional production. This is mainly due to the reduced use of machines (hire costs, fuel, maintenance), labor (fewer field operations) and fertilizer
- Both cultivation methods were neutral in terms of crop yield
- Net return in the case of CA were 4% higher than conventional farming. However, the difference is not statistically significant.

Table 9 Cost and benefits of rice production under conventional tillage technique and CA (average of demonstration fields 2007)

Cost/benefit items	**Conventional. Tillage (LE./fed)**	**CA (LE./fed)**	**Difference (LE./fed)**	**Difference (%)**
Costs				
Labor	419.1	350.4	68.7	16.4
Animal	57.4	26.6	0.8	53.6
Machines	581.3	471.1	110.2	19.0
Seeds	118.9	124.2	5.3	4.4
Fertilizers	274.9	227.9	47	17.1
Chemicals	196.5	180.6	15.9	8.1
Total costs	1645.8	1407.0	238.8	14.5
Benefits				
Yield (t/fed)	4.5	4.4	0.1	2.2
Price (LE/ton)	1247.9	1253.8	5.9	0.47
Value of product (L.E.)	5644.9	5561.3	83.6	1.5
Net return	3999.1	4155.2	156.1	3.9
Gross margin (%)	242	295		

The economic results for the 2008 rice season showed a very similar picture and are therefore not presented.

As for wheat, economic data from demo fields could only be collected from the winter season 2007/2008. Table 10 shows small savings in cost of production (LE 24/fed) and a slightly increased net return (LE 92/fed) of wheat under CA compared with conventional tillage. The main cost savings of CA are those for labor.

Table 10 Cost and benefits of wheat production under conventional tillage technique and CA (average of demonstration fields 2007)

Cost/benefit items	**Conventional Tillage (L.E./fed)**	**CA (L.E./fed)**	**Difference (L.E./fed)**	**Difference (%)**
Costs				
Labor	658	632	26	4.0
Animal	-	-	-	-
Machines	370	373	3	1.0
Seeds	157	158	1	0.06
Fertilizers	338	336	2	0.6
Chemicals	94	94	0	0
Total costs	1617	1593	24	1.5
Benefits				
Yield (t/fed.)	2.1	2.1	0	0
Price (L.E./t)	2666.7	2666.7	0	0
Value of product (L.E.)	5600.0	5600.7	0	0
Net return	3983.0	4007.7	24.7	0.7

Table 11 shows in the case of berseem under CA a small cost increase (LE 60/fed) against conventional tillage. This increase was due to the use of direct seeders whereas conventional farmers use few machinery for cultivation and broadcast the seed into the rice stubble. CA also produced a substantial decrease in net return of LE 1860/fed (29%). The reason for this was already discussed in detail above, direct seeding of the fine-seeded berseem into full straw residues requires special attention during harvest otherwise resulting in reduced and delayed germination. Green matter yields were reduced by about 18% compared with conventional cultivation and therefore also the net returns fell by some 30%.

Table 11 Cost and benefits of berseem production under conventional tillage technique and CA (average of demonstration fields 2007)

Cost/benefit items	**Conventional tillage (L.E./fed)**	**CA (L.E./fed)**	**Difference (L.E.)**	**Difference (%)**
Costs				
Labor	163	163	0	0
Animals	-	-	-	-
Machines	165	225	60	27
Seeds	158	158	0	0
Fertilizers	92	92	0	0
Chemicals	-	-	-	-
Total costs	**578**	**638**	**60**	**10**
Benefits				
Value of product (L.E.)	7080	5280	1800	25
Net return (L.E.)	6502	4642	1860	29

Awareness creation and training

Since CA is a knowledge intensive technology, training and teaching of researchers, extension advisors and farmers is an important factor for its introduction and dissemination. All project training activities were farmer-centered aimed at providing farmers with the practical know-how to efficiently use the new technology. At the core of the project's knowledge transfer stood the on-farm demonstrations which were closely related to training events such as field visits in which researchers, extension advisors and farmers (both project participants and outsiders) met and discussed technological issues. Also workshops (initial, mid-term and final) were organized to which many researchers and technicians from other institutions were invited. The objectives of these workshops were the presentation of project achievements, program planning and awareness creation for a wider public. The project implementation process was frequently covered by local TV stations and once during the concluding workshop by Euronews the TV information channel of the European Union.

Conclusions and recommendations

The FAO project introduced CA in Egypt and showed that CA is a technically and economically feasible alternative to existing crop production practices. Crops such as rice and wheat have been successfully tested under CA and achieved yields equal to those grown under conventional practices. These results were very encouraging because they have already been achieved at the beginning of the introduction process of CA. Experience from many other countries with agro-ecosystems similar to the one in Egypt indicate that the productivity of CA generally shows an upward trend due to an increasingly better mastering of the technology by farmers and the medium/long term benefits of CA such as higher soil fertility and soil health. Therefore it can be expected that also in Egypt productivity of grain crops under CA will increase in future.

Other major immediate advantages of CA over conventional systems were savings in time, energy (fuel) and labor needed for land preparation and crop management. The project also demonstrated the advantages of CA practices for weed control, crop water consumption and improvement of soil conditions for crop development.

The project showed that even Berseem can be grown after rice with full residue retention without significant yield penalties. However, this requires some adaptation and special attention in the handling of straw residues and stubble hight at rice harvest, which during the project duration could not be successfully introduced on all project farms.

The project showed that at present Conservation Agriculture is the only on-farm technology with the potential to substantially reduce air pollution through rice straw burning and thus to contribute to environmental conservation. However, CA needs to be spread on a much larger scale in the Nile delta in order to achieve a substantial impact on air pollution.

The project was successful in creating wider interest in CA at the level of the MoA, the scientific community and farmers. Dissemination of Conservation Agriculture among farmers at a larger scale requires a continued involvement of the GOE in the future through establishing a collaborative effort of researchers, technical assistants, extension officers and farmers. More on-farm research efforts are needed to adapt CA to farmers' conditions and for the formulation of suitable recommendations.

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