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COST-BENEFIT ANALYSIS OF CONSERVATION AGRICULTURE IMPLEMENTATION IN SYRDARYA PROVINCE OF UZBEKISTAN

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Most irrigated lands of Central Asia suffer from land degradation, and unsustainable agricultural practices are one of the factors contributing to land degradation. Conservation agriculture (CA) is seen as a way to mitigate land degradation and rationalize resource use. The aim of this article is to investigate the efficiency of CA implementation in the Syrdarya province of Uzbekistan, Central Asia by carrying out a cost-benefit analysis (CBA). The CBA was conducted for a hypothetical situation where the farm decides to switch from conventional agriculture to CA. Unlike the previous studies, this study investigates complete crop rotation cycle in the long-term period. The study outcomes suggest that investment in CA implementation results in positive incremental benefit if the advantages of CA are monetized.

Keywords: cost-benefit analysis, conservation agriculture, permanent bed system, Uzbekistan

Introduction

Land degradation is widespread in the agricultural lands of Central Asia resulting in productivity decline and affecting the lives of local people. Unsustainable land management is considered to be one of the main factors of land degradation resulting from the lack of incentives to invest in sustainable land management (Pender et al., 2009). More than a half of agricultural land in Uzbekistan suffers from land degradation. Land degradation problems are associated with the crops grown and farming technologies practiced (Pulatov et al., 1997; UNECE, 2010). Scientists see conservation agriculture (CA) as an effective and sustainable practice for agricultural production (Hobbs et al., 2008). FAO (2015) identifies three main components of CA: minimum soil disturbance, permanent organic soil cover and crop rotation. CA is widespread in South America, and has been practiced in other parts of the world (Derpsch and Friedrich, 2009). Kassam et al. (2012) argue that CA adoption in Central and West Asia and North Africa can result in economic and environmental benefits.

Considering land degradation and water scarcity problems, sustainable land management practices have been studied since the early 1990s at a small number of pilot projects in mainly wheat and cotton production in irrigated areas of Uzbekistan (Pulatov et al., 1997; Pulatov, 2003). Research on conservation agriculture in irrigated agricultural lands of Uzbekistan showed that conservation practices decrease soil salinity, increase soil moisture retention (Egamberdiev, 2007; Pulatov et al., 2012; Devkota et al., 2015b), and decrease soil erosion and soil compaction (Pulatov, 2007; Khaitov, 2014). Research evidence illustrates that conservation agriculture can give similar yields as conventional tillage with less time and energy input and better environmental sustainability (FAO, 2009; Pender et al., 2009; Devkota et al., 2013a). The results suggest that conservation agriculture may lead to higher gross margin than conventional agriculture due to higher yields and lower input costs (FAO, 2009; Pulatov et al., 2009; Tursunov, 2009; Bronzes, 2014; Boboev et al., 2015).

However, in 2013, only 2450 ha of agricultural land were under conservation agriculture in Uzbekistan (AQUASTAT, 2015). Unawareness of the benefits of CA can be the reason that farmers do not practice CA. Even if conservation technologies have higher net benefits per hectare, limited availability of imported equipment can hinder adoption of new technologies. In addition, there is no sufficient scientific evidence to support extensive implementation of CA in Uzbekistan (Kienzler et al., 2012).

Economic profitability is an important requirement for the adoption of any agricultural practice. Cost-benefit analysis (CBA) is a tool to assess the economic efficiency of a project or a policy (Hanley, 2001). Many studies have applied CBA to evaluate conservation practices in the different places of the world, and these studies show that the benefits of conservation practices depend on the regions studied and the type of conservation measure (Lutz et al., 1994; Knowler and Bradshaw, 2007; Palm et al., 2014). For this reason, it is necessary to evaluate conservation agriculture applied to agroecological conditions and cropping patterns of Uzbekistan (Kienzler et al., 2012). Since the state plays an important role in agriculture in Uzbekistan (Rudenko et al., 2012), it is necessary to provide evidence on economic feasibility of conservation agriculture to policymakers.

The available literature on economic assessment of CA in Uzbekistan has used gross margin analysis and did not include cover crop production (Tursunov, 2009; Bronzes, 2014; Boboev et al., 2015; Devkota et al., 2015a). To the best of our knowledge, economic cost-benefit analyses (CBA) of CA implementation in Uzbekistan, which considers investment costs and flow of benefits in the long term, are not available in the peer-reviewed literature.

The article makes a novel contribution to existing literature by providing an economic assessment of CA in Uzbekistan through a cost-benefit analysis considering investment costs. Unlike previous economic assessments, our cost-benefit analysis evaluated complete crop-rotation cycle in the long-term period, including in the calculations cover crop production costs and opportunity costs of crop residue (Derpsch, 2003). Considering the data constraints on long-term yield improvement in conservation agriculture in Uzbekistan (Pittelkow et al., 2015), we decided to include monetized crop residue value as a nutrient in the calculations as an alternative approach.

Materials and methods

Cost-benefit analysis of conservation agriculture implementation was done for a hypothetical farm that practises conventional agriculture. The hypothetical farm has all the necessary machinery for conventional agriculture, except a harvesting combine. The farm rents the harvesting combine from the government or private companies. The following crop rotation is applied:

cotton (*Gossypium hirsutum* L.) – winter wheat (*Triticum aestivum* L.) – maize (*Zea mays* L.). Conventional agriculture is based on tillage and no crop residue is left on the field.

Conservation agriculture to be implemented includes planting on permanent beds, permanent soil cover and crop rotation. In conservation agriculture, the following crop rotation is applied: cotton (*Gossypium hirsutum* L.) – winter wheat (*Triticum aestivum* L.) – mung beans (*Vigna radiata* L.) – rye (*Secale cereale* L.). Tillage is not practiced in conservation agriculture. The wheat straw is left on the field after harvest, and rye is used as a cover crop.

The investment needed to switch to conservation agriculture consists of the following steps:

1. sub-soil ploughing of the field;
2. laser-guided levelling of the field;
3. making permanent beds;
4. purchase of conservation agriculture planter for direct planting.

Planter Vence Tudo SA 9400 (made in Brazil) was selected because it can be mounted to locally available tractors with 70–80 horsepower. It was estimated that one planter Vence Tudo SA 9400 could plant approximately the area of 50 ha in one vegetation season, and, for this reason, the cost-benefit analysis was done for a farm of 50 ha.

Information about physical amounts of costs and benefits of CA implementation were obtained through personal communication with the farmers of Pakhtakor farm, where on-farm study on conservation agriculture has been going on, in Syrdarya province and the TIIM (Tashkent Institute of Irrigation and Melioration) study farm in Tashkent province, and literature review. Cotton and winter wheat yield results in conservation agriculture and conventional agriculture were assumed to be equal because there was no long-term data on yield results of conservation agriculture.

The study applied economic cost-benefit analysis to assess the net incremental benefits of conservation agriculture implementation (Dreze and Stern, 1987). Net Present Value (NPV) was used as the sole evaluation criterion. NPV compares the costs of conservation agriculture implementation and the net incremental benefits from conservation agriculture over the assessed time in present terms. NPV was calculated in the following way:

$$NPV = \sum B_t (1+r)^{-t} - \sum C_t (1+r)^{-t} \qquad (1)$$

where:
the summations run from $t = 0$ (the first year) to $t = T$ (the last year) B_t is value of benefits in year *t* and C_t is value of costs in year *t, r* is a discount rate (EU, 2014)

Ideally economic cost-benefit analysis uses the shadow prices of all inputs and outputs, and world market prices as next-best alternative when shadow prices are not available (Boardman et al., 2011). World market prices of inputs and outputs in 2014 in US dollars were used in this cost-benefit analysis. These world prices were used directly without converting them into shadow prices because, in the absence of accurate shadow prices, it is preferable to use actual market prices to avoid computational shortcomings related to derivation of shadow prices (UNIDO/IDCAS, 1986).

The social discount rate (SDR) was used for discounting. The SDR was considered to be equal to the marginal rate of return on private investments (Boardman et al., 2011). SDR or *r* was adjusted for inflationary expectations according to the following formula:

$$r = \frac{(i-m)}{(1+m)} \qquad (2)$$

where:
m is annual inflation rate, *i* – nominal interest rate

The interest rate on bank deposits in 2014 was used in the calculation of SDR. The highest before-tax return rate on bank deposits equalled 12% in 2014 in Uzbekistan (Ravnaqbank, 2015). The government forecasted inflation rate to be about 7% in the long- term period, and 7% inflation rate was used in the calculation (CBUz 2015). In this case, SDR equalled 4.67%.

The farmer uses a 15% rate of depreciation for the machinery but the actual lifespan of the machinery can be longer. Thus, it was assumed that the farmer had to make reinvestment in the conservation agriculture planter every 7 years. The time horizon of 14 years was selected for the discounting as information on other long-term recurring investments was limited.

In this work, two different approaches were applied towards the valuation of crop residue of rye and wheat: (1) the Non-Monetized Crop Residue Approach (NMCRA), where benefit of crop residue as mulch was not monetized and therefore excluded from the CBA (only opportunity cost of crop residue as a feed to livestock was included in the CBA); and (2) the Monetized Crop Residue Approach (MCRA), where benefit of crop residue as mulch was monetized and included in the CBA (net benefit from crop residue was crop residue value as a nutrient minus crop residue opportunity cost as a feed). According to the extension service of the Iowa State University, the value of crop residue to the farmer equals the monetary value of nutrient content of the crop residue. The nutrient value of the crop residue was determined by dry weight nutrient concentration multiplied by the market value of the equivalent amount of artificial fertilizer (Lal, 1995; Edwards, 2014). As we assumed that yield results in conservation agriculture and conventional agriculture were equal and do not change over time, we avoided double counting of crop residue benefit. If we had and included long-term yield results in the calculations, the yield results change in conservation agriculture would reflect the impact of conservation agriculture, including crop residue effect.

We tested the sensitivity of our results to the following variables: (1) the social discount rate; and (2) prices of inputs and outputs that are affected by implementation of conservation agriculture. First, NPV was calculated with the alternative social discount rate. The before-tax average rate of return on corporate bonds in Uzbekistan was used to calculate the alternative SDR for sensitivity analysis. "Kapitalbank", one of the leading private banks, issued corporate bonds with rate of return which equalled 11% in 2014 (Kapitalbank, 2014). The inflation rate based on CPI was forecasted to be 10% in the long-term period (IMF, 2015). In this case, SDR equalled 0.91%.

Second, worst, average and best price case scenarios were used to evaluate the price change influence on the CBA results. Five years (2010–2014) minimum, maximum and average prices of the relevant inputs and outputs were used for the scenarios. The average price case scenario used 5-year average prices. The worst price case scenario used the prices that lead to lowest CBA results; the best price case scenario used the prices that lead to the highest CBA results. For example, CA implementation lead to fuel savings and, consequently, higher fuel price results in higher NPV and, therefore, five-year maximum diesel price was used for the best price case scenario.

Results and discussion

The overview of CBA results of switching to CA in the NMCRA is given in Table 1. In the first year, the initial investment was made. As machinery is depreciated in 7 years, farmer had to make an investment in conservation planter in 8th year. Savings in fuel and labour costs led to a positive net incremental benefit in cotton production. In the first year, cotton production in CA led to a small incremental benefit because the farm switched to CA in the middle of cotton production in conventional agriculture and still most of the tillage operations were performed. However, winter wheat production in CA did not lead to net positive incremental benefit because the value of the savings on fuel and labour in CA did not offset the opportunity cost of wheat straw as a feed. Lower production costs and higher mung bean prices made mung bean production in CA more profitable than maize production in conventional agriculture. Rye production yielded mostly costs, namely costs of production and lost opportunity cost of rye straw. Total net incremental benefit of CA in a crop rotation cycle was positive but it was not enough to offset the investment costs in the assessed period. Thus, the CBA of switching to CA for 50 ha farm resulted in negative NPV, which equalled USD -4,581.

In the MCRA, wheat and rye straw value as a nutrient were monetized and included in the calculations. In wheat production, the sum of savings on fuel, labour, rope for straw baling and wheat straw value as a nutrient was higher than opportunity cost of wheat straw as feed. It resulted in positive net incremental benefit in winter wheat production. Negative net incremental benefit was still observed in rye production because rye straw value as a nutrient was lower than rye productions costs and rye straw opportunity cost as a feed. Net incremental benefits of the cotton and mung bean production were the same as in the NMCRA. Positive incremental benefit in winter wheat

Table 1 The overview of CBA results of switching to CA in the NMCRA, USD 50 ha^{-1}

Year	Investment	Cotton, net incremental benefit	Wheat, net incremental benefit	Mung bean, net incremental benefit	Rye, net incremental benefit	Total	Annual discounted cash flow
0	-31,763					-31,763	-31,762.68
1		49				49	46.87
2			-5,212	10,724		5,512	5,030.97
3		14,170			-13,533	637	555.58
4			-5,212	10,724		5,512	4,591.80
5		14,170			-13,533	637	507.08
6			-5,212	10,724		5,512	4,190.97
7		14,170			-13,533	637	462.82
8	-4,000		-5,212	10,724		1,512	1,049.35
9		14,170			-13,533	637	422.42
10			-5,212	10,724		5,512	3,491.23
11		14,170			-13,533	637	385.54
12			-5,212	10,724		5,512	3,186.47
13		14,170			-13,533	637	351.89
14			-5,212	10,724		5,512	2,908.31

Table 2 Overview of CBA results in the MCRA, USD 50 ha^{-1}

Year	Investment	Cotton, net incremental benefit	Wheat, net incremental benefit	Mung bean, net incremental benefit	Rye, net incremental benefit	Total	Annual discounted cash flow
0	-31,763					-31,763	-31,762.68
1		6,710				6,710	6,410.17
2			1,449	10,724		12,173	11,110.19
3		14,170			-10,515	3,654	3,186.52
4			1,449	10,724		12,173	10,140.35
5		14,170			-10,515	3,654	2,908.36
6			1,449	10,724		12,173	9,255.17
7		14,170			-10,515	3,654	2,654.48
8	-4,000		1,449	10,724		8,173	5,671.48
9		14,170			-10,515	3,654	2,422.77
10			1,449	10,724		12,173	7,709.88
11		14,170			-10,515	3,654	2,211.28
12			1,449	10,724		12,173	7,036.86
13		14,170			-10,515	3,654	2,018.25
14			1,449	10,724		12,173	6,422.60

production and increase of incremental benefit in rye production led to positive NPV, which equalled USD 47,396 (Table 2). Thus, monetizing the crop residue value as a nutrient makes CA implementation beneficial.

As a part of sensitivity analysis, the impact of alternative social discount rate (SDR) on NPV of incremental benefits was tested. Alternative SDR (0.91%) is much lower than the base SDR (4.67%). Therefore, CBA with alternative SDR in both approaches resulted in positive NPV, USD 4,037 for the NMCRA and USD 70,881 for the MCRA. This again proves that choice of discount rate can substantially influence the result of the CBA.

Second, the worst price case, best price case and average price case scenarios were analysed. The worst price case scenario led to negative NPV in both the NMCRA (USD -104,790) and the MCRA (USD -54,557). It means that in case of "unfavourable" prices, implementation of CA would not lead to positive incremental benefit. In the average price case scenario, CBA in the NMCRA resulted in negative NPV (USD -23,021), whereas CBA in the MCRA led to positive NPV (USD 39,564). This suggests that if relevant factors' prices had the same variation pattern in the 14-year period, the price variation would not influence the economic efficiency of CA. In the best price case scenario, positive NPV was achieved in both the NMCRA (USD 48,725) and the MCRA (USD 124,569). Thus, even if the crop residue value as a nutrient was not considered in the CBA, "favourable" prices could be the condition for approving CA implementation.

In this research, net incremental benefits in winter wheat and rye production were negative in the NMCRA, because savings on fuel and labour costs did not offset the cost of crop residue retention and cover crop production. Similarly, Boboev et al. (2015) stated that savings on tillage were lower than cost of mulching based on the findings of field experiment in 2008–2009 in the Khorezm province, Uzbekistan. Furthermore, Ram et al. (2011) reported that net returns in wheat-maize system in conservation agriculture were lower due to the high cost of straw mulch based on the field study (2003–2008) in Ludhiana, India. Das et al. (2014) also mentioned high costs of mulch in field study (2010–2013) in New Delhi, India. These suggest that our results confirm findings in the wider scientific literature on this topic.

In the NMCRA, use of the alternative social discount rate changes the NPV from negative to positive. However, in the study by Scott and Farquharson (2004) the financial CBA results of investments (1970–2002) in conservation farming in Australia were positive and insensitive to discount rate changes.

In the MCRA implementation of CA resulted in positive NPV. However, the MCRA assumed that nutrients of crop residue become immediately available to the plants, so it did not take into account the rate of mineralization of crop residue (Janzen and Kucey, 1988) and nutrients' availability to the plants. The MCRA might result in the overestimation of the crop residue nutrient value. In an ideal case, the benefits from the crop residue as a nutrient should be counted at the time of nutrient availability to the plant. There is a qualitative understanding of importance of crop residue as a nutrient source, but knowledge limitation exists in quantification of amount and timing of nutrient release from crop residue (Shepherd et al., 1996).

In both approaches, the assumption that the yields in conservation agriculture are equal to the yields in conventional agriculture can result in underestimation of CA benefits because improvement of yield results is considered to be a long-term benefit of CA (Govaerts et al., 2005; Knowler and Bradshaw, 2007). Short-term studies showed similar or higher cotton and winter wheat yields in CA in Uzbekistan than those of conventional agriculture (FAO, 2009; Tursunov, 2009; Devkota et al., 2013b). Moreover, together with monitoring soil fertility, application of precision agriculture in CA could lead to improvement in fertilizer application and increase of income (Jenrich, 2011; Sapkota et al., 2014). In other words, the crop residual would improve soil quality and decrease the mineral fertilizer use (Das et al., 2014). Irrigation water use was not included in the CBA due to absence of water use data. Water use data could improve economic results of CA. According to Devkota et al. (2013a), in CA water productivity (ratio of yield to total water input) was higher than water productivity in conventional agriculture in winter wheat and cotton production in the study in the Khorezm province, Uzbekistan.

Our study was focused on on-site costs and benefits. However, quantification of the off-site benefits of CA as reduced downstream sedimentation, fertilizer loadings, increased carbon sequestration and wildlife habitat improvement could substantially influence CBA results (Uri et al., 1999; Knowler and Bradshaw, 2007).

Conclusion

Conservation agriculture leads to resource savings, but it also has additional costs such as opportunity cost of crop residue and cover crop production. The study findings suggest that savings in fuel and labour are not always sufficient to offset additional costs of conservation agriculture. Even if the net incremental benefits in a crop rotation cycle were positive, it was not sufficient to recover the investment costs in the long-term period. On the other hand, including in the calculations a rough estimate of the monetary value of crop residue as a nutrient source made the investment in conservation agriculture profitable. This indicates that implementation of conservation agriculture is promising to result in positive net incremental net benefit to the society if the benefits of CA are monetized.

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