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The Role Of Glycyrrhiza Glabra For Remediation Of Soil Fertility

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Abstract – Soil salinity is a major threat to the sustainability of agricultural production and rural livelihoods in the Mirzachul area in Uzbekistan. Leaching, a traditional practice to cope with salinity through flushing of soils with fresh water in order to remove excess salts from the topsoil, is no longer feasible due to disrepair and inefficient operation of the drainage networks. As a result, salinized lands are either giving very low yields and income or are abandoned, which is negatively affecting rural livelihoods. As an intermediate solution, the cultivation of licorice (*Glycyrrhiza glabra*) is proposed as a viable alternative, as it rehabilitates salinized soils and improves their fertility - so that major crops can be again grown profitably in these abandoned or highly saline lands. In addition to its positive impact on the sustainability of agricultural production in irrigated areas, licorice cultivation can also increase farm income thanks to the high economic value and marketability of its roots and the value of its biomass as livestock feed.

Keywords – Northern and Central Asia, salt tolerance, rehabilitation, common practice, enterprise, cotton, Syrdarya province.

I. INTRODUCTION

Globally, the total area of lands affected by secondary salinity was earlier reported to be 351.5 mln ha, with the largest area in Northern and Central Asia - 91.6 mln ha (Szabolcs, 1989). Middleton and Thomas (1997) also reported that human induced salinization affects 47.9 mln ha in the dry areas of the world. Gnassemi *et al.* (1995) estimated that the cost of salinity to global agriculture was then 12 bln USD annually. IMF (2008) cites the World Bank estimates that annual losses in agricultural output due to land salinity are equal to 31 mln USD in Uzbekistan, while the economic losses due to the agricultural land going out of use equals roughly USD 12 mln annually. Total annual losses in agricultural production in Uzbekistan from all forms of land degradation and lack of maintenance in irrigation and drainage systems were estimated to be equal to almost 1 bln USD (World Bank, 1999a), which equaled to about 5% of Uzbekistan's total GDP, as reported by World Bank (1999b).

Inefficient irrigation water management in the absence of appropriate surface or subsurface drainage systems leads to a rise in groundwater table resulting in the accumulation of secondary salts in the plant root zone. When soluble salts accumulate in the amounts above the threshold salt tolerance limits of crops, the process of secondary salinization begins to adversely affect agricultural production, as well as the environmental health and the economic welfare of the people (Rengasamy, 2006). As a result of salinity build-up, the productivity of irrigated agriculture in Central Asia has been undergoing a gradual degradation over the last three decades. This problem has led to declining farm incomes in the rural areas in Uzbekistan. Failing irrigation infrastructure, unclear property rights, misguided agricultural polices, and lack of support for agricultural research and technology transfer have been found to be largely responsible for this problem (Babu and Tashmatov, 2000; UNDP, 2003; CACILM, 2006a; Orlovsky and Orlovsky, 2002; Kushiev *et al.,* 2005; Paroda, 2007). Kushiev *et al*. (2005) cite from World Bank (2003) that the costs of rehabilitation of the salinized soils in Mirzachul can be more than 2 bln USD.

In Syrdarya province of Uzbekistan, soil salinity build-up is resulting in the abandonment of agricultural lands due to significant decreases in crop yields. Leaching is a common practice in Central Asia for reducing soil salinization (Vyshposky *et al.,* 2008). Generally, before the cropping season, soils are flooded with irrigation water which is expected to flush the salts down to deeper soil layers and away into the drainage system. However, leaching has become more and more excessive in recent years, now sometimes being carried out three or four times before the cropping season. Given the present inefficient operation of drainage systems, leaching is often actually worsening the soil salinity, as salts are only moved vertically in the soil layer but not removed from the land (Ibrakhimov and Awan, in prep.). Moreover, excessive leaching may also lead to removal of essential nutrients from the soil (Vyshposky *et al*., 2008). Importantly, in view of the expected growing shortage of fresh water resources in the region as a consequence of climate change and ever increasing water demands (Martius *et al*., 2008), the leaching practice which involves up to 6,000 m^3 of water per hectare is not sustainable. Three types of leaching are practiced now by farmers in Syrdarya province: 1) deep flooding on highly saline areas, 2) shallow flooding on medium saline areas, and 3) furrow leaching (or pre-sowing irrigation) on low saline areas. However, majority of on-farm drainage systems need significant rehabilitation for normal functioning. The problem becomes even more complicated because of the present nature of dividing responsibilities for irrigation system maintenance. The State is responsible for inter-farm level and farmers for on-farm level. However, most of the farmers do not have the necessary financial resources to maintain the proper functioning of on-farm drainage systems in their fields; moreover, given the current land tenure system, with farmers having only *usufructuary* rights through a long-term lease of land without full ownership, there is no incentive for a significant long-term investment in land rehabilitation.

The salinity problem is exacerbated by raising groundwater level (Ibrakhimov, 2005), uneven field leveling, mono-cropping of cotton which is a national strategic crop (Wehrheim and Martius, 2008) and lack of agricultural machinery for appropriate cultivation and tillage (Tursunov, in prep.), and vast water losses at the farm level as a result of wasteful furrow irrigation method (Conrad *et al*., 2007). The choice of crop rotations is fixed by the State; consequently, cotton and wheat are planted on the majority of arable lands. Alternative crops are planted only on a limited area. As a result of all these factors, almost 3.3 mln ha of irrigated areas (53% of the total) are affected by secondary salinization in Uzbekistan (CACILM, 2006b). About 88% of the agricultural lands in Syrdarya are affected by different degrees of salinity (FAO, 2003). The salinization of agricultural land is spreading rapidly, leading to the abandonment of up to 3% of irrigated area in Syrdarya province annually (Kushiev *et al*., 2005). This is endangering the livelihoods of already impoverished rural communities.

In the absence of appropriate drainage systems which are expensive to maintain, it is prudent that other measures with the potential for rehabilitation of saline soils be adopted. In this study, we intend to investigate the economic potential for addressing the salinity problem through cultivating a native, salinity-tolerant value crop, licorice (*Glycyrrhiza glabra*), in the highly saline areas of Mirzachul. The phyto-remediation experiences acquired in Uzbekistan for reducing deep percolation losses of water leading to rising groundwater tables through cultivating licorice could prove useful elsewhere in reclamation and management of saline soils having high groundwater table conditions.

Licorice grows naturally in many regions of the world, especially in West Asia and North Africa, the Caucasus and Central Asia (Lange, 1998). It grows best in the fertile soils of the river valleys (Houseman and Lacey, 1929). In 1970s the area under licorice industrial cultivation in Uzbekistan stretched to some 16,000 ha in Karakalpakstan region of Uzbekistan. In addition, licorice was growing naturally on considerable areas in the deltas of the Amudarya, Syrdarya and Zaravshan rivers of Uzbekistan (Ashurmetov *et al*., 2005). However, presently licorice grows only on a very limited area in the deltas of the above-mentioned rivers, and on the banks of small rivers in Fergana valley, Tashkent, Bukhara, Khorezm and Samarkand provinces (ibid.). This is mainly because of the over-exploitation of natural areas of licorice growth and virtual disappearance of its industrial cultivation. However, currently there are no comprehensive data or maps on licorice growing areas in Uzbekistan.

The aboveground height of licorice can reach up to 1.5 meters. The licorice plant has a strong root system, reaching up to 17 meters in length. With such a root system licorice is able to access ground water thereby effectively reducing the risk of upward movement and secondary salinization of the profile. Due to its morphological attributes, the plant is persistent and may become a weedy species in cultivated lands where it is indigenous and is difficult to control without appropriate management. It is quite robust, highly competitive and successfully expands by out-competing other plants. Licorice can also grow well in low fertility lands thanks to its ability to fix atmospheric nitrogen.

Although licorice is considered an easy plant to grow (Whitten, 1997; Olukoga and Donaldson, 1998) there is little published information defining the agronomic requirements to optimize root production (Douglas et al., 2004). Licorice is normally grown from rhizome cuttings or harvested crowns taken from mature crops and laid out in shallow furrows (Molyneux, 1975; Anon., 1982; Singh et al., 1984). Normally, the roots are harvested from only the top 1 m, but where complete root harvests have been made, fresh root yields of 50 t/ha have been reported (Molyneux, 1975; Duke, 1981). Licorice root for use as a medicinal herb is required to contain at least 4% glycyrrhizin (glycyrrhizic acid) (American Botanical Council, 1998; WHO, 1999); this is generally achieved after four to five years of cultivation. The cultivation of inter-row crops to generate income until the pharmaceutical glycyrrhizin levels are attained, is possible, however, it is not recommended (Singh et al., 1984), as it may decrease licorice root yields (De Mastro et al., 1993; Marzi et al., 1993; Bezzi and Aiello, 1996).

In addition to its effects in lowering ground water levels and hence, salinity, the yields of crops planted after licorice can be higher by as much as 3-6 times, as compared when no licorice has been used for soil remediation (Kushiev *et al.,* 2005). Licorice roots as well as biomass could serve as a valuable livestock fodder. In addition, licorice has important uses in numerous industries (Singh *et al.,* 1984; Nieman, 1957; Chandler, 1985; Fenwick *et al*., 1990; Olukoga and Donaldson, 1998), such as: i) pharmaceutics, ii) food and beverages, iii) fertilizers, iv) chemicals and paints, v) metallurgy, vi) ceramics, vii) paper production, viii) textiles, ix) perfumery, x) tobacco, etc.; thus, licorice roots have a significant export potential.

During the Soviet period, the marketing of licorice in Uzbekistan was carried out by a centralized body Soyuzlakritsa based in Charjou, Turkmenistan. Since the independence, the licorice exports are regulated by the Government of Uzbekistan through licensing procedures. In recent years, there has been an expansion in the internal licorice processing capacities. Currently, at least two licorice processing factories are reported to be operating in Uzbekistan. However, there are several dozens of firms dealing, among other activities, in the export of dried licorice roots. The market structure for licorice roots operates in a quite chaotic way, extending from officially registered companies dealing in licorice roots to private un-regulated entrepreneurs. The exact figures on export of licorice roots are not available.

Licorice roots in Uzbekistan now come from exploitation of naturally growing licorice areas. In this regard, over-collection might lead to the reduction of plant cover and biomass, as is already occurring in some other countries and Central Asia itself (Le Houeârou, 2002), and exacerbate the on-going land degradation and desertification in Uzbekistan. Therefore, cultivation of licorice as part of the cropping system offers two important possibilities: 1) opportunity to take advantage of growing global market demand, and 2) opportunity to rehabilitate abandoned and highly saline lands and return profitable crop production to these areas. This analysis intends to evaluate the potential of the licorice cultivation in highly saline lands of Uzbekistan to enhance the economic and environmental sustainability of these lands.

II. METHODS AND MATERIALS

A. Research site

The Syrdarya province of Uzbekistan covers some 428 thousand hectares, of which 84% are considered to be potentially suitable for irrigated agriculture. Currently, total irrigated area is about 293 thousand hectares (WEMP Sc-A1, 2001). Out of the total irrigated area, 54% is considered to be affected with low salinity, 25% with moderate salinity and 7% with high salinity (FAO, 2003). The province has a total population of 1.9 million people, of whom 68.5% reside in the rural area. The GDP per capita in the region is estimated to be equal at about USD 2,080 calculated at purchasing power parity, which is 73.4% of the national average (UNDP, 2006).

The region is located in Mirzachul (Hungry Steppe) zone, which is a vast plain, bordering with Turkestan mountain chains in the south, the Syrdarya river in the north and east, and Kyzylkum desert in the west. It was incorporated into agricultural production following a massive land reclamation effort in the 1970s (FAO, 2001; Khasankhanova, 2003). The area is now one of the major cotton producing belts in Uzbekistan and Central Asia. In the hot dry summers evaporation losses of water are extremely high in Mirzachul facilitating an upward movement of the salts leading to peak salinization rates in absence of rainfall event. Present lack of investment in rehabilitation, repair and cleaning of drainage systems has become a major factor significantly diminishing the positive effects of conventional salinity management practices such as leaching which is in turn leading to infrastructure deterioration and land degradation.

Main crops cultivated in the area are cotton and wheat. In addition, the livestock represents an important source of household livelihoods in the rural areas. Average yields of cotton and wheat in Mirzachul area are low: 1.5 t/ha and 1.75 t/ha, respectively (Kushiev *et al*., 2005).

B. Methods

Cultivation of licorice for the remediation of salinity-affected areas was studied by the Gulistan State University at Navbahor collective farm of Syrdarya province from 1999-2003 under a partial funding from the Asian Development Bank (ADB) as reported by Kushiev *et al.* (2005). Starting from 2005, the output of this research has been further expanded through a research for development program for out-scaling to farmer demonstration plots under the project on “Enabling Communities in the Aral Sea Basin to Combat Land and Water Resource Degradation Through the Creation of ‘Bright’ Spots”, also funded by ADB.

Under the research at Navbahor collective farm, the experimental site was located in a highly saline abandoned area. There were two treatments laid out in autumn 1999 in adjacent fields: i) control without licorice (10 ha), ii) licorice cultivation (13 ha). These fields were typical of abandoned farmer fields in Mirzachul area due to high salinity. The average yield of licorice hay at the experimental plot made up 3.66 t/ha in 2001 and over the next two years reached the maximum of 5.11 t/ha in 2003. The licorice root yield attained 5.63 t/ha and 8.55 t/ha in 2002 and 2003, respectively. Winter wheat and cotton were planted in three replications in the total area of 1 ha for each crop in autumn 2003 and spring 2004, respectively. The size of the control fields both for winter wheat and cotton were equal to 1 ha each. The average yields of winter wheat were equal 0.87 t/ha and 2.42 t/ha for control and licorice treatments, respectively. The average yields of cotton were 0.31 t/ha and 1.89 t/ha for control and licorice treatments, respectively.

The ex-ante analysis of licorice cultivation presented further is based on general agronomic attributes of licorice as well as the on-farm yield data from the above mentioned research activities at the Navbahor farm. The purpose of economic evaluation is to analyze the profitability of licorice cultivation under different price, inflation, capital cost and yield scenarios. The data and assumptions used in the economic evaluation are based on cost benefit analysis using enterprise budgets. The production cost data, including variable (inputs) and fixed costs (taxes and depreciation), were collected through interviews with 10 farmers participating in the licorice out-scaling activities under the Project. As the licorice cultivation is undertaken in cycles corresponding to the maturing of licorice roots with required pharmaceutical properties, a long-term cost-benefit analysis was applied and indictors such as net present value (NPV) was computed.

Taking into account the cyclical nature of development of licorice roots, the agronomic results of the experiments (Kushiev *et al.*, 2005) and farm operations cost data collected through farmer interviews, the cost-benefit analysis model uses the following five scenarios, all covering the period of 10 years:

1. Licorice is cultivated during 10 years in the highly saline land (*Scenario LC10yrs*)
2. Licorice is cultivated for 5 years in the highly saline land, then the farmer switches to cotton-wheat rotation for the following 5 years (*Scenario LC5yrsCW5yrs*)
3. Cotton-wheat rotation is practiced in the highly saline area, without rehabilitation of land using licorice (*Scenario No LC*)
4. Current average profitability of cotton cultivation in Mirzachul, all levels of salinity combined. (*Scenario No LC, Only Cotton*).

Taking into account that it is quite difficult to remove licorice roots before planting cotton and wheat after land rehabilitation with licorice, costs of cleaning the fields from licorice roots before planting cotton or wheat are incorporated into the costs of the Scenario LC5yrsCW5yrs. In addition to the roots, licorice provides biomass as livestock feed. Therefore, analysis takes into account both the economic benefits from the licorice roots, as well as benefits from its biomass as fodder.

Assumptions:

1. The annual discount rate is equal 10% .
2. The prices and costs are kept unchanged over the years, their levels in the year 2007 are used, and they are expressed in US Dollars (USD). The conversion rate from UZS to US dollar used in this study is equal to 1,250 UZS per 1 USD.
3. Licorice roots reach marketable quality at the fifth year of cultivation, and once harvested, the roots take another five years to regenerate to the appropriate quality requirements.

4. The price of licorice root is taken as 100 USD/t (in line with the market prices in Uzbekistan for licorice root in 2010-2019), and the price of licorice hay as 15 USD/t (not traded locally).

III. Results and discussion

The economic analysis of the four scenarios showed that these highly saline abandoned lands cannot be cultivated profitably under cotton or wheat at this level of salinity. The scenario *LC10yrs* comes out slightly more profitable than scenarios *LC5yrsCW5yrs* and *No LC only cotton* (all salinity levels), and much more profitable than cultivating either cotton or wheat in highly saline areas, which is economically unprofitable (Table 1).

Table 1. Profitability of licorice cultivation under different scenarios in Mirzachul area of Uzbekistan

Indicators	**LC10yrs**	**LC5yrsCW5yrs**	**NO LC**	**No LC Only Cotton**
Revenues, USD/ha	1,132	1,829	1,217	3,548
Costs, USD/ha	880	1,607	3,800	3,380
Net benefit, USD/ha	252	222	-2,583	169
Benefit cost ratio	1.28	1.13	0.32	1.04
Annualized net benefit, USD/ha	25	22	-258	17

Sensitivity analysis

Factors influencing the choice of options

Several factors, such as changes in licorice root price, licorice hay price, cotton price, wheat price and discount rate can influence the option between the different scenarios described above (Tables 2-6).

As the price of licorice root increases, other factors remaining equal, the LC10yrs scenario becomes the most profitable (Table 2). The break-even licorice root price for the scenario LC10yrs is 67 USD/t, and 54 USD/t for the scenario LC5yrsCW5yrs. Hence, at the price of licorice root lower than 67 USD the scenario LC5yrsCW5yrs is economically more preferable than the scenario LC10yrs.

Table 2. Simulated effects of licorice root prices on the annual net benefits (USD/ha)

Scenarios	**60 USD/t**	**100 USD/t**	**150 USD/t**	**200 USD/t**
LC10yrs	-6	25	64	103
LC5yrsCW5yrs	3	22	46	70
No LC	-258	-258	-258	-258
No LC, Only Cotton	17	17	17	17

As the price of licorice hay increases, all other factors remaining equal, the LC10yrs scenario again becomes the most profitable (Table 3). As the licorice hay prices go lower, the scenario LC5yrsCW5yrs becomes more profitable. The breakeven point, in terms of licorice hay price, is 5 USD/t for scenario LC10yrs, and about 0.5 USD/t for the scenario LC5yrsCW5yrs. These low levels of licorice hay prices take into consideration that licorice hay is presently not traded as a commodity in the local markets.

Table 3. Simulated effects of licorice hay prices on the annual net benefits (USD/ha)

Scenarios	4 USD/t	10 USD/t	15 USD/t	20 USD/t
LC10yrs	-1	13	25	37
LC5yrsCW5yrs	6	15	22	30
No LC	-258	-258	-258	-258
No LC, Only Cotton	17	17	17	17

The rise in the cotton price increases the average profitability of growing cotton in Mirzachul as a whole (scenario No LC, Only Cotton), but it does not improve much the performance of growing cotton in the highly saline areas. Even at the price of raw cotton at 500 USD/t (unlikely in the near future), the scenarios including some licorice cultivation remain more profitable than growing cotton without licorice rehabilitation in the highly saline areas (Table 4). As the price for cotton increases, the scenario LC5yrsCW5yrs is more preferable than the scenario LC10yrs. We should also note that at the current prices for cotton and licorice root, as a whole in the Syrdarya province, our cost-benefit model shows that licorice cultivation can be more profitable than cultivating cotton, however, it is not feasible in practice, mainly for two reasons: i) increased production of licorice is likely to bring the licorice root prices down unless the internal demand also grows at similar pace and/or the Government and the private sector actively promote and realize the substantial exports of licorice roots; ii) even if substantial licorice root exports can be achieved, the cash flow cycle in licorice cultivation is 5 years, while in cotton it is just one cropping seasons, which makes cotton more preferable for the farmers who primarily depend on crop cultivation for their livelihoods.

Table 4. Simulating the effects of cotton prices on the annual net benefits (USD/ha)

Scenarios	350 USD/t	400 USD/t	450 USD/t	500 USD/t
LC10yrs	25	25	25	25
LC5yrsCW5yrs	22	31	40	49
No LC	-258	-252	-246	-240
No LC, Only Cotton	17	68	118	169

At the price of wheat at about 150 USD/t, the LC10yrs model is the most profitable. However, as the prices for wheat increases further (which we are observing presently), the LC5yrsCW5yrs model becomes more profitable (Table 5).

Table 5. Simulating the effects of wheat prices on the annual net benefits (USD/ha)

Scenarios	150 USD/t	200 USD/t	300 USD/t	350 USD/t
LC10yrs	25	25	25	25
LC5yrsCW5yrs	22	39	72	88
No LC	-258	-232	-180	-154
No LC, Only Cotton	17	17	17	17

One of the assumptions of our analysis was constant prices, hence the interest rate used in our sensitivity analysis is the real interest rate, without the effect of inflation. At the interest rate of 10%, corresponding approximately to the present real interest rate in Uzbekistan, the scenario *LC10yrs* is more profitable than the other scenarios. However, a rise in the interest rate makes all options of cultivating crops on highly saline soils less profitable. However, the interest rate sensitivity analysis demonstrates that even at 40% interest rate, cotton cultivation in Syrdarya province as a whole (Scenario *No LC, Only Cotton*), still remains profitable, while the other scenarios have negative profitability. However, even with the higher interest rate, licorice cultivation scenarios (LC10yrs and LC5yrsCW5yrs) are found to be more economic than cultivating only cotton in the highly saline areas (The Scenario No LC) (Table 6).

Table 6. Simulated effects of discount rate on the annual net benefits (USD/ha)

Scenarios	10%	20%	30%	40%
LC10yrs	25	9	0	-5
LC5yrsCW5yrs	22	10	2	-3
No LC	-258	-258	-258	-258
No LC, Only Cotton	17	13	10	8

As a general conclusion, the sensitivity analysis points out that at the current price levels for licorice root and the expected upward trends of these prices, since the current licorice root prices in Uzbekistan are under-valued as compared to the world prices, the most profitable option is cultivating only licorice on highly saline areas. However, the scenario LC5yrsCW5yrs is found to be more adopted to the current context in Uzbekistan, since it is less exposed to various risks associated with price and interest rate volatilities than other scenarios. This conclusion is also re-enforced by the current Government policies which give prominence to strategic food and cash crops (wheat and cotton), and the larger employment generation effects of cotton cultivation. Thus, scenario LC5yrsCW5yrs makes it possible for farmers to switch to cotton and winter wheat cultivation, once the land is rehabilitated and cleaned from licorice roots, increasing the economic and environmental sustainability of these otherwise abandoned lands.

IV. Conclusions

Cultivation of licorice, a highly salt and drought tolerant crop known for its capacity to lower ground water levels, presents a feasible alternative in the remediation of highly saline abandoned soils. Cost benefit analysis indicates that growing licorice on saline soils does not only have highly effective attributes of land reclamation and remediation, but also is quite profitable for farmers after the roots start being collected in the fifth year. These results and the potential impacts they suggest are important given the vast irrigated areas of Uzbekistan considered to be highly saline, or abandoned - 192 thousand hectares (FAO, 2003). The analysis also shows that cultivation of food (wheat) and commercial (cotton) crops after soil remediation with licorice, leads to increased yields and profitability of these crops, as compared to the option without land rehabilitation using licorice. At the same time, certain constraints of licorice cultivation, such as initial investment costs and negative cash flow during the first 4 years, underdeveloped access to international markets, difficulty of eradicating licorice roots from the field once planted should be given due consideration. The analysis showed that switching to cotton-wheat rotation after the fifth year of licorice cultivation was the optimal option in the current policy, economic and social environment.

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