Environmental and financial viability of CDM afforestation in dryland Uzbekistan

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Introduction

Since its establishment in 2001, Clean Development Mechanism (CDM) of the Kyoto Protocol remains the first primary international program for carbon offsets. Despite numerous shortcomings in the "learning-by-doing" implementation, CDM has managed to establish a global, $2.7 billion worth market for greenhouse gas emission reductions, involving over 70 developing countries (Gillenwater and Seres, 2011). Afforestation and reforestation, the only land-use activities eligible under CDM, have not been considered a success as evidenced by their 0.7% share of the total number of the CDM projects approved. As main reasons identified were high transaction costs, precluding in particular small-scale projects, the lack of forestry expertise in the project preparation, convoluted methodological and documentation procedures, non-permanence of offsets, as well as issues in CDM governance and in accounting of emissions reductions (Schoene and Netto, 2005; Locatelli and Pedroni, 2006; Thomas et al., 2010).

On the bright side, CDM forestry was recognized to link efforts of reducing emissions and combating land degradation (FAO, 2000). The CDM forestry projects primarily target unproductive and degraded lands, where the criterion of "additionality" is easier to justify (http://cdm.unfccc.int/Panels/ar). Thus the contribution to sustainable development can be enhanced by promoting such projects in agricultural countries, where cropland degradation is a significant threat to livelihoods.

Irrigated drylands that are responsible for over 30% of the total agricultural production, have been underrepresented on CDM agenda due to their presumably low carbon (C) sequestration potential. Global land suitability assessment for CDM *a priori* excluded irrigated areas assuming their high productive value (Zomer et al., 2008), little feasibility of forestry practices due to high irrigation demand of trees, and low cost-effectiveness of dryland projects (Michaelowa A., email communication).

This brief outlines the afforestation of degraded irrigated croplands from the perspective of land reclamation, carbon sequestration potential and cost-effectiveness. Much of the evidence on the remedial value of afforestation has been previously summarized (Khamzina et al., 2011) based on long-term field studies in dryland Uzbekistan, Central Asia. These results laid the ground for estimating the financial viability of retiring degraded irrigated cropland to establish tree plantations (Djanibekov et al., manuscript in preparation).

Afforestation in reclamation of degraded irrigated croplands

Among the principal culprits of low agricultural productivity is the land degradation from salinization that is affecting 30% of all irrigated cropland. In Uzbekistan, almost a half of the arable lands is saline (MAWR 2010) resulting in annual losses of 31 mln USD while withdrawal of highly saline lands out of agricultural production amounts annually to 12 mln USD (World Bank 2002). The adverse effects of land degradation on Uzbekistan's economy are significant given that agriculture accounts for 22% of GDP and employs 33% of labor (Statistical Committee 2010).

Reclamation of saline land via leaching demands large water inputs and a costly maintenance of drainage systems. The growing regional water scarcity could render such technical solutions little feasible for unproductive croplands, requiring alternative strategies. One adaptive option is converting the unproductive fraction of the cropland to high-C stock systems of salt-tolerant tree species. Areas experiencing shallow groundwater tables, commonly found within the degraded irrigated croplands, are viewed as promising for afforestation given the possibility to reduce the irrigation water demand of forestry (Khamzina et al., 2009a).

The study region Khorezm

The land rehabilitation and productive potential of tree plantations was studied in a 2-ha sized experimental afforestation site established on degraded cropland in the lower reaches of the Amu Darya River, in the Khorezm Region of Uzbekistan (Khamzina et al., 2011). The region's entire irrigated area is subject to soil salinity in various extents due to elevated, saline groundwater tables. Khorezm is located within the transition zone of the Karakum and Kyzylkum deserts and is characterized by an arid, extremely continental climate. Mean annual rainfall of 100 mm fall mostly outside the growing season and is exceeded by the potential evapotranspiration of 900–1000 mm. Salt-tolerant trees were expected to develop extensive root systems for effectively tapping into the groundwater given the shallow levels of 1.3–1.8 m and relatively low salinity of about 1.8 dS m^{-1} in Khorezm (Ibrakhimov et al., 2007).

The population of Khorezm numbers 1.7 million people with 70% being rural. Agriculture accounts for 35% of the regional GDP (Statistical Committee 2010). The entire cropland of 270,000 ha is cultivated under furrow or flood irrigation. About 50% and 20% of arable land is allocated to cotton and winter wheat, respectively. Both crops are part of the national development strategy and grown according to the state procurement targets (Djanibekov et al. 2010). Some 15-20% of the cropland area is reported as low productive but is cropped nevertheless to fulfill the area-based production targets (that are set low for the marginal lands). The commitment to cotton and winter wheat would prevent alternative cropping but mechanisms exist to request an exemption of the unproductive cropland from the state directives. Considering the risk of losing lease contracts of farmland that may restrain long-term investment in land use (Djanibekov et al., 2010), a short-rotation forestry is viewed as a suitable option because, with an appropriate choice of species, it is able to deliver benefits in a relatively short run.

Ecosystem services generated from land-use change

A judicious choice of species for afforestation would maximize associated environmental services such as biological drainage of elevated groundwater table, improvement of soil nutrient stocks, biodiversity, and amenities (shadow, shelter for livestock, bee foraging, scenic beauty) contributing to overall ecosystem health. Tradable non-timber commodities such as fuelwood, fodder, fruits, and, under CDM, carbon offsets, could provide the cash flows to cover early investments and increase financial attractiveness of this land-use change.

Promising candidate species for afforestation were assessed using multiple physiological and socio-economic criteria that singled out the currently underutilized *Elaeagnus angustifolia* L., *Ulmus pumila* L. and *Populus euphratica* Oliv. (Khamzina et al. 2006). The establishment and growth of these tree species were field-tested under deficit irrigation during 2003-2009, as previously described (Khamzina et al. 2008; 2009b). Irrigated with 80-160 mm yr^{-1}, the plantations successfully established on highly saline soils with the root-zone electrical conductivity (EC) over 20 dS m^{-1}, underlain by shallow (0.9–2.0 m) groundwater with an EC ranging between 1-5 dS m^{-1} (Khamzina et al., 2008). Following the cessation of irrigation after two years, the trees relied on the groundwater alone and produced 10-60 t ha^{-1} yr^{-1} of above-ground biomass (stand density was 5,714 trees ha^{-1}). Thus, by drawing on relatively untapped groundwater resources, afforestation can contribute to water saving as “unused” irrigation water from afforested plots could become available for use on productive croplands.

The ability of some tree species for biological nitrogen (N) fixation can make tree-based systems on degraded land self-sufficient in N nutrition thus requiring no N-fertilization. The amount of N_2-fixed by *E. angustifolia* initially averaged 0.02 t ha^{-1} yr^{-1}, peaked at 0.5 t ha^{-1} yr^{-1} during the next two years, and thereafter stabilized at 0.3 t ha^{-1} yr^{-1} (Khamzina et al. 2009b). According to the classification of Dommergues (1995), species with a N_2-fixing potential of 0.1–0.3 t ha^{-1} $year^{-1}$ are regarded as highly efficient and *E. angustifolia* would thus fit this category. Consequently, the establishment of tree plantations on the degraded cropland increased soil total N stocks in the upper 20 cm layer by 6-30% in five years. The increase in plant-available soil N was the highest under *E. angustifolia* stands. Increases in the concentrations of plant-available phosphorus of up to 74% were significant irrespective of tree species, suggesting an efficient nutrient pump (Khamzina et al. 2009b). This improvement in soil fertility is evidence that afforestation with mixed-species plantations can be a sustainable land-use option for degraded irrigated drylands.

The carbon sequestration rate in woody biomass, above- and below-ground, ranged between 3 and 27 t ha^{-1} yr^{-1}, depending on species and tree age. Seven years following afforestation, the bio-carbon stock of the mixed-species tree stand averaged 74±13 t ha^{-1}. Furthermore, the soil organic C stocks rose by 10-35%, adding 2-7 t C ha^{-1} to the upper 0-20 cm soil layer and thus increasing soil fertility. The N_2-fixing *E. angustifolia* was the most effective tree species in soil C sequestration. If such C sequestration in tree biomass occurs in an afforestation project certified under the CDM, the resulting C payments could encourage afforestation in degraded cropland areas.

Financial viability of CDM afforestation

Financial analyses considered the seven-year rotation period for the tree plantations. The Net Present Value (NPV) of afforestation included tCERs over the crediting period of same duration and non-timber products i.e. leaves (as fodder), fruits and fuelwood. The opportunity costs of the land-use change from annual cropping to plantation forestry were estimated through the gross-margins of the strategic crops cotton and winter wheat cultivated in low-productive areas in Khorezm.

Depending on tree species, the NPV of afforestation ranged between 415 and 3,934 EUR ha^{-1} even under the high discount rate of 14% (the latter is according to the Central Bank of Uzbekistan, as of July 2009). The cultivation of cotton and winter wheat on the marginal cropland resulted in annual losses of 231 and 52 EUR ha^{-1}, respectively (Table 1), despite that the optimal irrigation supply was assumed available for these crops to maximize their yields. Besides the low crop yields on marginal land, the estimated financial losses were mainly caused by the low procurement prices.

Table 1. Net Present Value (NPV) of annual cropping and afforestation after seven years, with and without temporary Certified Emission Reductions (tCERs) and assuming optimal irrigation supply for crops

Type of crop/ Tree species	NPV, EUR ha^{-1}	NPV including tCERs, EUR ha^{-1}	Irrigation amount, mm yr^{-1}
cotton	-231	-231	600
winter wheat	-52	-52	540
E. angustifolia	3,934	4,132	80-160*
P. euphratica	1,185	1,456	80-160
U. pumila	415	512	80-160

*Tree plantations were irrigated only during first two years

The cost structure of CDM afforestation showed that the highest costs occurred at the onset of the project (Figure 1). These consisted of transaction costs, associated with a small-scale CDM project, in the amount of 206-361 EUR ha^{-1} and of plantation establishment costs comprising 436-543 EUR ha^{-1}.

The largest share of the revenues was provided by fruits (3,612 EUR ha^{-1}) harvested annually in *E. angustifolia* stands. The fruit production tended to decline over time given the high stand density (5,714 trees ha^{-1}) which is not favorable if fruit production is to be prioritized. Fuelwood provided an important contribution to the total revenues generating up to 2,369 EUR ha^{-1} in *P. euphratica* stands. Such new fuelwood source could help reduce the illegal cutting of natural tugay and desert forests and provide a supplementary energy option in rural areas where over 50% of the rural population has insecure or reduced access to gas supplies1 (UNFCC 2001). Potential profits from foliage as fodder were relatively low.

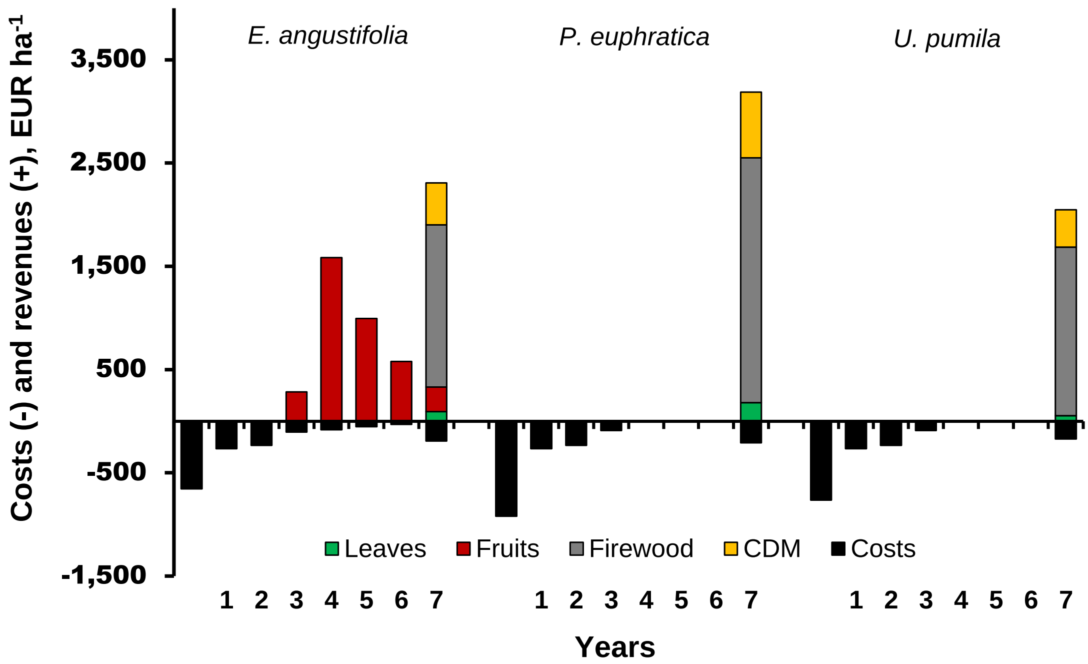

Figure 1. Cost and benefits of afforestation over a seven-year rotation period

[1] http://www.ieguzexpo.com/page/exhibition/clean_energy/71/res

At the average global price of 3.26 EUR per tCER, C payments measured 5-19% of the total revenues from afforestation and ranged from 97 to 271 EUR ha^{-1} depending on tree species. This amount alone would be insufficient to cover the initial investments.

Given the low irrigation requirement of trees (13-30% of the crop water demand), irrigation water saving as a result of afforesting degraded cropland would amount to 35,000-40,000 m^3 ha^{-1} over seven years. This conservative estimate can be more than doubled by including the annual cropland demand for leaching. Expressed in monetary terms using a water price of 0.015 EUR m^{-3} (Djanibekov 2008), the irrigation water saving would amount to 519-606 EUR ha^{-1}. Therefore, accounting for the availability of irrigation water in determining the tCER price would increase the value of dryland afforestation under the CDM scheme.

Conclusions

Overall evidence on ecosystem rehabilitation and financial viability of afforestation under low irrigation supply suggests that setting aside degraded cropland parcels for plantation forestry is an attractive option for irrigated drylands, where shallow groundwater tables prevail. The legislative aspects of retiring degraded croplands and related land tenure issues would need to be amended for exploring Uzbekistan´s small-scale forestry participation in the international carbon market under CDM. At the current tCER price, little revenues can be expected from carbon sequestration alone, thus C payments need to be considered in the framework of other benefits, such as provisioning of non-timber products. Nevertheless, in the absence of other incentives for land rehabilitation via tree plantings, the carbon sequestration reward remains the major motivation to initiate investments in afforestation of degraded irrigated croplands in Uzbekistan.

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