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RESEARCH PAPER

Carbon Cautious: Israel's Afforestation Experience and Approach to Sequestration

Alon Tal · Jessica Gordon

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Abstract During the past 60 years, afforestation has transformed Israel's landscape, with forests planted or planned on 10% of the country's land, much of it with less than 300 mm of annual precipitation. After early efforts to establish a successful commercial timber industry failed, recreation and ecosystem services came to dominate forestry policy objectives. Given Israel's status as a 'developing country' under the Kyoto Protocol, forests' economic potential through carbon sequestration has been explored, but has not yet proven to be compelling. Several considerations cooled initial enthusiasm for seeking international carbon credits through afforestation. These include administrative obstacles associated with international accreditation, limited potential economic profitability, and ethical considerations. Rather, a voluntary offsetting program was adopted, allowing donors to plant trees in Israel, that balance individual carbon emissions. Afforestation in drylands exhibit meaningful potential to counteract chronic carbon loss due to land degradation. As trees planted in Israel's semi-arid regions exhibit surprisingly high carbon sequestration properties that are comparable to forests in temperate Europe, the potential for offsetting may become a growing factor in local forestry policy once Israel begins to regulate CO_2 emissions.

Keywords Forestry policies · Israel · Carbon · Sequestration

A. Tal (✉)
Mitrani Department of Desert Ecology, Ben Gurion University of the Negev,
Sede Boqer, Israel Chairman of the Land Development Committee, KKL-JNF,
Jerusalem, Israel
e-mail: alontal@bgu.ac.il

J. Gordon
US Environmental Protection Agency, Washington, DC, USA

Introduction

Like other Mediterranean countries, such as Turkey (Turkey Ministry of Environment and Forestry 2008) and Jordan (WRI 2006) Israel has initiated a national afforestation strategy. In many ways, however, Israel's forestry experience is unique not only in the Mediterranean and Middle Eastern context, but globally. In much of the country, newly planted trees have transformed a land that for centuries was denuded of vegetation. Historically, much of the motivation behind Israel's forestry policies was linked to ideological impulses of 'redeeming' what was perceived as a neglected and eroded homeland. Given the country's climatic constraints, questions about sustainability in Israel's planted forests are frequently raised and influence afforestation techniques and strategies. While sustainable forestry efforts emphasize ecological balance, economic viability is a key pillar of sustainability equations that should be part of the policy discourse. In this context, foresters need to consider the economic potential associated with carbon sequestration.

Traditionally, Israeli forests were designed to contribute to national soil conservation efforts and more recently to enhance recreation for the public and ecological corridors for wildlife (Kaplan 2009). During the last two years, the carbon sequestration potential of local dryland afforestation efforts has been assessed by Israel's forestry authorities in the Keren KaYemeth L'Yisrael (Jewish National Fund—hereinafter KKL). Trees planted on Israel's semi-arid land show surprisingly high levels of carbon sequestration and may make a modest contribution to greenhouse gas balance (Rotenberg and Yakir 2010). Accordingly, establishing afforestation carbon credits under the UN's CDM (clean development mechanism) has not been deemed worth pursuing. The rationale behind the country's present forestry carbon-sequestration policy has never been clearly articulated or documented, but may be valuable for other developing countries.

The paper presents a historic and institutional description of Israel's forestry programs. It then reviews the basic science of carbon sequestration via afforestation, considers available data regarding the potential carbon sequestration potential in Israel's dryland areas, and draws policy implications in light of international rules and principles.

A Brief History of Forestry in Israel

The degraded condition of Israel's landscape during the first half of the 20th century is well documented by aerial photographs and myriad descriptions by travelers (e.g. Twain 1996). Such bleak descriptions are difficult to fathom today. Jerusalem is surrounded by thick canopies of conifer forests and much of the Galilee is green. About 10% of the country's 22,000 km^2 area is designated as forest, most of it on semi-arid and dry-subhumid land (Kaplan 2009).

Institutionally, management of Israel's forests is overseen by the public corporation the KKL (Jewish National Fund), rather than by a government agency. The KKL was involved in land reclamation, agricultural development and afforestation before Israel was established in 1948. Rather than establish a new government agency after the country gained independence, the KKL retained de facto responsibility for tree planting in 1949 and since 1961 has served as the de jure forestry agency (Tal 2003).

The KKL also controls 13% of Israel's land, much of which it leases at considerable profit, operating a strong international fundraising network in over 20 countries. Consequently, Israeli forestry programs have always enjoyed a relatively stable and independent source of financing. This affects policy-makers' economic perspective and has led to the present focus on recreational, ecological and natural heritage objectives in the national forestry strategy.

During the 1950s, tree planting, especially in areas that were unsuitable for agricultural cultivation provided employment for tens of thousands of refugees, and was consistent with the 'pioneering spirit' of the period. Forestry enjoyed political support from the highest levels, including Israel's founding Prime Minister, David Ben Gurion (Weitz 1970). The reasons for the country's passion for tree planting evolved over time, beginning with nationalism and ensuring Jewish sovereignty over purchased land (Cohen 1995), providing employment for immigrants (Segev 1986), and more recently supporting recreational opportunities as well as ecological restoration (Ginsberg 2000). Eventually, 260 M trees were planted, with stands located in semi-arid areas with as little as 250 mm of rain per year—a level generally considered too low for dense woodlands. In fact, Israel has successfully created conifer forests in these parched regions with 80% sapling survival rates that can create full canopy cover (Atzmon et al. 2004).

For most of the country's history, Israeli forests were dominated by conifers, in particular, the Aleppo pine or as it is locally called 'Jerusalem Pine' (*Pinus halepensis* (Amir and Rechtman 2006)). During the early 20th century, when KKL foresters were experimenting with various species, Jerusalem pine consistently out performed the indigenous oak trees. By 1938, 98% of the trees planted by the KKL were *Pinus helepensis*. Four of the tree's advantages commonly cited by the country's first generation of foresters were climatic versatility, ability to thrive in a variety of soils (including rocky land), ease of planting and cultivation, and rapid growth rate (Tal 2003).

The country's nascent ecological community, however, was not enamored with the conifers and vociferous in its disapproval of the new monocultures. Its representatives argued that this species supplanted natural habitats and was unpleasant aesthetically for visitors. Eventually, nature resolved the debate because early successional forest plantings are bound to adapt according to ecological processes and because of the perils of monocultures. Tree species began to change as a result of the use of seed sourced from oversea (Schiller et al. 1986; Grunwald et al. 1986). Because of their genetic unsuitability to the local ecological conditions many succumbed to the aphid known locally as the Aleppo pine baste scale (*Matsucoccus josephi*) that thrived on the young pine woodlands (Mendel 1984).

With 70% losses in some forests, a new approach became imperative. More diverse plantings soon became the norm, with foresters preferring broad-leaf Mediterranean species including oak, pistachio, carob, tamarisk, Syrian pear, storax, hawthorn and madrone (Ginsberg 2006). These grow more slowly, but are better able to withstand local insects, fungi and fires. Israeli woodlands now support a rich variety of wildlife and are home to picnic sites, playgrounds as well as hiking and mountain biking trails (Kaplan 2009).

Individual tree species, at least formally, have enjoyed statutory protection since the enactment of a 1926 Forest Ordinance by the British Mandatory government (Avni 2007). With the promulgation of a National Master Plan or 'NMP 22 for Forests and Foresry' in 1995, forest conservation made a quantum leap forward (Kaplan 2009). The plan formalized both the borders of the country's forests and the makeup of the varying stands (Israel Ministry of Interior 1995). Formal zoning designations were established for 200,000 ha of forests—one tenth of the nation's land—based on ecological and recreational criteria. A further 30,000 ha of land, designated as various forest types, remain to be planted. Most of the available reserves are located in Israel's southern drylands—the Negev desert.

Israel's current forestry management practices rely on applied research projects, often conducted by external academic institutions. For example, a recent study showed that despite traditional tendencies for planting saplings during the peak of the winter rains, when soils reach their highest level of saturation, success rates among autumn plantings are far higher (Litminovich et al. 2008). As a result, planting schedules have been modified. Tree planting in dry subhumid zones which used to be extremely dense (4000 to 6000 stems per hectare, sph) now begin with about 1000 sph which are subsequently thinned. In the semi-arid regions, tree density is only 300 sph. Nonetheless, because of the extensive site preparation required to direct runoff to irrigate the saplings and retain rainwater for maximum utilization by individual trees, the costs of the southern, low-density stands are higher ($US 10,000/ha) than conventional planting ($7500/ha).

The primary reason for high tree density in initial stands planted in Israel was the somewhat ingenuous aspirations of the foresters in the nascent state to establish a local timber industry (Orni 1969). With time, the competitiveness and profitability of Israel's dryland lumber proved disappointing, and recreational and ecological objectives came to dominate Israel's afforestation strategy (Tal 2006).

When a new sustainable forestry policy was approved by the KKL Board of Directors in 2006, it acknowledged that sustainable development should allow for 'economic utilization of forests and of other areas planted with trees'. Yet, the profitability of tourist concessions and the contingent value associated with recreational experiences of millions of forest visitors were deemed more important economically (KKL 2006). The only meaningful exception to this rule has been a program to promote the planting of eucalyptus trees for commercial timber among private farmers. This program only became possible after Israel's agricultural sector underwent an economic crisis during the 1980s, and a low maintenance, unirrigated crop which can thrive on salinized land was sought. Because they grow so quickly, eucalypts have always been raised commercially in a variety of developing countries for construction lumber, particle board and biomass for energy, frequently being harvested in less than 10 years (Zohar and Gafni 2010). In practice, today about 100,000 saplings are distributed without charge annually in Israel to local honey production operations and 200,000 for eucalyptus tree plantations (Brand 2009).

Beyond eucalypts, national timber yields are limited to 100,000 tons per year, having grown only slowly throughout recent decades (KKL 1997). This provides only 10% of domestic wood production as well as considerable heating materials for Israel's nomadic Bedouin and Arab communities. While such production is far from trivial, Israeli forestry policy has long ceased to be driven by timber production considerations. Whether the potential benefits associated with carbon sequestration could change present economic calculus remains a question requiring assessment.

Carbon Sequestration and Afforestation: Scientific Assumptions

Policies to promote 'biological sequestration' can take two basic forms, namely conservation of existing carbon stocks (interventions to prevent deforestation and degradation of existing forests), and sequestration through afforestation, reforestation or by increasing carbon stocks in existing forest lands through forest management (Smith 2009). Additional sequestration benefits through agricultural methods (no or low-till agriculture) can also contribute, but are beyond the scope of this paper.

With the planet losing 3% of its forested lands between the years 1990 and 2005, most analysts agree that on a global scale *conservation* is the more promising strategy. The UN's Food and Agriculture Organization estimates that emissions from deforestation or degradation of existing forests contribute as much as 25–30% of total greenhouse gas emissions (FAO 2006). Incentives to facilitate REDD (Reducing Emissions from Deforestation and Degradation) have been the focus of discussion at meetings of the UNFCCC, (Miles and Kapos 2008) even as such programs are still not accepted for trading under the CDM.

In dryland countries with limited natural biomass or with considerable past deforestation, potential emissions of carbon from forestry loss is trivial. There is simply not that much carbon to conserve. But planting trees might be able to add meaningful carbon stock to these areas. Researchers have started to assess the potential of dryland afforestation for increasing carbon stocks. (Conant et al. 1998; Geesing et al. 2000; Paul et al. 2002; Grunzweig et al. 2003; Lal 2004; Nosetto et al. 2006; Goberna et al. 2007).

Accordingly, the potential of afforestation to sequester carbon was the only sequestration alternative seriously considered by the KKL as the issue of climate change and afforestation emerged internationally. The agency relied on a rich reservoir of information and scientific study.

Frequently, climate experts distinguish between two parallel carbon cycles. The larger cycle involves geological processes. Over vast periods of time, biomass is converted to sedimentary deposits, which produce the natural gas, oil and coal that fuel economies. But it is the shorter carbon cycle which is relevant to afforestation strategies for addressing global warming. There are in fact five pools in which carbon stocks can be found in forest ecosystems. These include *the trees themselves* (living and standing dead trees, with associated roots, stems, branches and foliage), *understory vegetation* (including shrubs, bushes, herbs and grasses), *fine woody debris on the forest floor* (tree litter and humus), *dead wood on the ground*, and *soil carbon* (USDA 2004). The wood that is harvested and removed from forests often remains as carbon in the form of furniture or buildings for many years. Ultimately this wood will also decay and return to the atmosphere as carbon or methane.

Trees are comprised of about 50% carbon. Accordingly, net carbon increases in ecosystem-scale carbon stocks are primarily found in the build-up of tree biomass above ground (Thuille and Schulze 2006). The sequestration associated with afforestation generally refers to the process in which trees fix carbon through photosynthesis, breaking down CO_2 from the atmosphere into basic amino acids or glucose (Soroos 1997). During the early stages of tree growth, the net flux of carbon from the atmosphere to the tree is rapid. With time, carbon loss through respiration begins to increase, as does net carbon loss from decomposition of plant material. With the death of a tree and decomposition, carbon is released to the atmosphere.

On a global scale, this tree-driven sequestration over time has led to massive uptake of carbon. Indeed, forests store over half of the world's organic soil and vegetation carbon. Yet carbon sequestration in tree biomass may be highly temporary; fires, diseases and other hazards facing forests can quickly cause decay and release tree-carbon that has taken decades to accrue into the atmosphere.

The role of forests in facilitating carbon sequestration in *soils* is of growing importance for climate change policy analysis (Lal 2005). Because organic carbon becomes encapsulated within stable micro-aggregates, microbes have no access to it and the resulting carbon enrichment is considered a more permanent process. Sequestration takes place as a result of three inter-related mechanisms: humification (or the collection of humus from the remains of plants and animals at varying stages of decomposition), aggregation and illuviation. Generally soil sequestration of carbon is divided into two components: soil organic carbon (SOC) and soil inorganic carbon (SIC)—the former of which is far greater in its volume. In both cases atmospheric CO_2 can be captured through management of vegetation, soil and water resources to increase soil carbon.

Because of past degradation of productive soil of the drylands through 'desertification', the potential for additional 'sink capacity' is particularly great. For example, research in Sudan shows enormous sequestration potential as an atmospheric sink when marginal agricultural areas are restored to their natural savannah state. In this case, about 80% of natural carbon levels was restored (Olsson et al. 2001; Poussart et al. 2004). Research in China and Inner Mongolia shows that crop biomass and seed production in the drylands are also positively associated with increased carbon in soils (Zhao et al. 2006).

The impact of afforestation on soil carbon levels depends on previous land use, forest age, and environmental conditions (Grunzweig et al. 2007). A comprehensive meta-analysis confirmed that when cropland is converted to forests, an 18% average soil carbon increase is measured in various climates, regardless of forest age (Guo and Gifford 2002). At the same time, tree establishment on native grassland and forests produced a net drop of 10–13% in SOC. As forests grew older—and critically as precipitation declines—these gaps diminish (Paul et al. 2002).

Climate, and especially precipitation, plays a major role in sequestration rates for soil. Soil carbon rates dropped when forests were established on natural grassland where precipitation ranged between 660 and 1070 mm/year. Such increases were consistently measured in dry areas, where annual rainfall dropped below 350 mm/year (Jackson et al. 2002). The invasion of woody vegetation into deserts and grasslands resulted in reduction of SOC at relatively moist sites (660–1070 mm precipitation) but increased SOC at dry sites (below 350 mm).

An important dynamic for Israeli decision-makers on carbon sequestration policy for drylands is the fact that afforestation in drylands counteracts what is essentially a default 'carbon loss' due to land degradation. As noted by Lal (2009, p. 441)—past president of the American Soil Society and Director of Ohio State University's Carbon Management and Sequestration Center—when reviewing the dynamics of desertification across vast stretches of Africa, Central Asia and South America:

> In contrast to the increase in anthropogenic emissions, the capacity of the land-based sink is regressively declining, probably because of the increase in the extent and severity of soil degradation and desertification. The exacerbation of the problem of degradation of soil and vegetation in the drylands has accentuated the gaseous emissions from these ecosystems while reducing the net primary productivity and uptake of CO_2.

In other words, in drylands afforestation not only produces a long-term net carbon gain through soil sequestration but also prevents the steady 'hemorrhaging' of carbon stocks in these marginal areas due to erosion, overgrazing and deforestation.

While the global rate of photosynthesis and plant respiration is not characterized well enough to determine the precise dynamics of global carbon storage, several trends are clear (Houghton 2007). Global warming and increased atmospheric CO_2 levels are likely to have a positive effect on photosynthesis levels and respiration rates in forests, leading to an acceleration of sequestration processes through rapid production of sugars (Ju et al. 2007). Ironically, the high levels of carbon dioxide may offer an explanation for one of the central conundrums facing atmospheric science: the relatively slow increase in carbon dioxide concentrations in the atmosphere, given the massive 22 billion ton emissions discharged annually by industry into the air. According to calculations of climatologists, after all the anticipated absorption by carbon sinks, about 7 billion tons remain unaccounted for. One of the explanations involves arid land afforestation. Botanical theory suggests that forests in dryland regions grow slowly, which should be reflected in modest CO_2 uptake. It appears, however, that there may have been massive underestimation of tree efficiency in these areas (Grunzweig et al. 2007).

Carbon Sequestration: The Global Context

Israel's forestry policies cannot be separated from the global legal context and its status and commitments under international agreements. Ever since the signing in May 1992 in New York of the UN Framework Convention on Climate Change, trees ostensibly enjoyed a comeback as cutting-edge components of modern environmental strategies. The convention's stated goal is 'stabilization of green house gas concentrations in the atmosphere at a level that will prevent dangerous anthropogenic interference with the climate system' (UNFCCC 1992). Meeting this goal not only requires inventorying (and controlling) emissions, but also expanding carbon sinks which are comprised of oceans and forests.

In a global context, humans are thought to release 6.6 gigatons of carbon each year by burning fossil fuels and releasing the carbon in the biomass. Recent estimates suggest that oceans absorb from the atmosphere approximately 2 more gigatons of carbon than they release (Rehdanz et al. 2006). Sequestration by terrestrial ecosystems involves an additional 1.2 gigatons (Stavins and Richards 2005). For equilibrium to be reached, either emissions of carbon need to drop by 3.4 gigatons or additional 'sinks' need to absorb these quantities—or a combination of the two strategies sought. Accordingly, carbon sequestration through tree planting is expected to become a central part of the global formula for environmental survival. Indeed, at the closing of the Academy Award winning documentary, the subtitles on the screen of *An Inconvenient Truth*, former U.S. Vice-President Al Gore urge viewers to 'plant trees'—and then 'plant more trees'.

Economic analysis suggests that carbon sequestration through afforestation may be cost-effective relative to other mitigation strategies. For example, when Harvard and Indiana University economists Robert Stavins and Kenneth Richards synthesized results of 11 cost-benefit assessments regarding afforestation sequestration potential in the USA; they estimated a range of $30–$90 per ton of carbon—for programs sequestering 500 million tons annually—a full one-third of current annual US carbon emissions (Stavins and Richards 2005). In stark contrast, the record of actual encouragement for afforestation under present international normative frameworks for combating climate change is poor. Indeed, the role of carbon sinks (or Land Use, Land Use Change and Forestry, LULUCF) in national and international strategies has been considered in depth by the International Panel on Climate Change, and debated in countless negotiation sessions of the 14 conferences of the parties to the UN convention (Prentice et al. 2001). It can be argued that the resulting legal and technical obstacles to certifying greenhouse gas reductions from tree planting reflect a high collective level of discomfort with forestry as a tool for addressing global warming.

An excellent example of the ambivalent attitude to afforestration sequestration is found in the Kyoto Protocol in which the parties to the Convention embraced a variety of trading modalities as part of the global implementation strategy (Kiss and Shelton 2004). Chief among these is the CDM system established under Article 12 of the Kyoto Protocol which allows developed 'Annex 1' countries to meet their greenhouse gas mitigation commitments by investing in mitigation efforts in a developing, non-Annex 1 nation. The CDM certification process is complex and requires, among other things, *additionality*: both that the project increases sequestration beyond an existing baseline (carbon levels without the project) and that the project would not have happened without the foreign investment encouraged by the CDM framework. Due to a variety of reservations, subsequent meetings of the parties ruled that the amount of 'carbon credits' which can be attained through forestry projects was limited to 1% (UNFCCC 2000).

In their domestic inventories countries can count the removal of carbon from the atmosphere due to management of grazing land, crop land management, forest management and revegetation. Yet, CDM credit is only recognized for afforestation and reforestation. Present reports from the UNFCCC Secretariat indicate that there are 1822 registered CDM projects that produce an impressive reduction of

318,128,353 'Certified Emission Units '(UNFCCC 2009). Of the 1,593 CDM registered projects world-wide, only 0.15 per cent are based on forestry and carbon sequestration (Earthwatch Institute 2010) in China, Moldova and India.

It seems that the potential of tree-planting is not being realized in executing present international commitments to address global warming. This is particularly unfortunate in the drylands where tree planting brings additional benefits including soil conservation, improved grazing and enriched quality of life.

Israeli Forestry and Carbon Sequestration Policy

As a dryland nation, still classified as a 'developing non-Annex 1 nation', which for 60 years has engaged in ambitious tree-planting, Israel's approach to the issue of carbon sequestration and forestry is of interest. It is worthy of note that prior to the UN's recent COP 15 regarding climate change in Copenhagen, Israel had no formal national strategy for greenhouse gas mitigation. As preparation for the conference, Israel's Ministry of Environmental Protection initiated such a document, but it was largely dismissive of potential reductions which could be attained due to afforestation activities (McKinsey 2009). At the December, 2009 Copenhagen gathering, Israeli President Shimon Peres announced the country's intent to make "best efforts" to implement a 25% voluntary reduction in overall carbon emissions from a "business-as-usual scenario" by 2030 but no mention was made of afforestation's role in reaching this objective (Peres 2009). Until recently, it was assumed that afforestation initiatives in semi-arid regions would contribute little to carbon sequestration efforts. Research headed by Professor Dan Yakir at the Weizmann Institute's Yatir forest research station suggests that contrary to prevailing theories of afforestation, this dryland forest is as efficient in sequestering carbon as those in more temperate regions. This is compatable with findings from afforesstation projects in semi-arid regions of Patagonia. (Nosetto et al. 2006)

Israel's largest forest (Yatir), with an area of 3000 ha, is comprised largely of *Aleppo pines* in an area with an annual rainfall averaging only 280 mm. Although located in the semi-arid northern Negev region, plantings are comparatively dense with canopy cover far above 30%. Schiller and Atzmon (2009) pointed out that in the East Mediterranean region, occurrences of native natural *Aleppo pine*—relic populations or single trees—are rare at sites receiving less than 400 mm average annual rainfall. Consequently, the tree's formal status in the dry Yatir climate should be of an introduced species.

Aleppo pine, selected for eco-physiological hardiness and drought resistance performs well environmentally (Atzmon et al. 2004). The research station reports that on average, 2.5 to 2.6 tons of carbon/ha are sequestered annually—comparable to the European average of 2.7 (Grunzweig et al. 2007). When the region had a rainy year, the carbon sequestration level reached 3.5 ton/ha.

Possible explanations for this high sequestration performance involve the ability of the trees to absorb carbon dioxide without opening stomata excessively, which compromises the tree's water balance through evaporation. Moreover, conifers planted are specially selected for their ability to thrive under drought and relatively saline conditions. Like any forest, carbon content is positively associated with phyotosynthetically active radiation, vapour pressure deficit, air temperature and soil water content. While woodlands in Israel for the most part rely entirely on rainfall for water, irrigation can improves net leaf assimilation along with general tree-ring growth (Klein et al. 2005).

Given the capacity of Israel's dryland trees to sequester carbon, should this high sequestration performance be translated into a money-making venture? This was the policy dilemma facing Israel's forestry agency.

Being categorized as a *developing* country, Israel can serve as a site for Clean Development Mechanism projects and can sell carbon reduction or sequestration credits to *developed* countries who can add the credits onto their carbon ceiling 'cap'. Israeli entrepreneurs enthusiastically pursued a variety of CDM projects including methane capture in landfills and dairies to increased industrial efficiency (Israel Ministry of Environmental Protection 2009). Theoretically, planting new forests could be another item on the menu of Israeli alternatives available to Annex I carbon investors. Indeed, in the Pearl River Basin in Guangxi Province, China, the first CDM credit was granted to a 2000 ha reforestation initiative which restored cleared and eroded land. Trees planted there included pine, liquid amber and eucalypts (Carbon Positive 2006).

A variety of factors led to the Israeli decision not to aggressively pursue a commercial carbon sequestration strategy based on afforestation, but to leave carbon credits to voluntary frameworks. There were three main reasons for this decision, namely administrative obstacles associated with UN accreditation, potentially low economic profitability and ethical considerations.

Accreditation for Dryland Forestry

A close look at the rules and limitations imposed by the UN convention on forestry 'sink' credits reveals a program that is designed to make CDM recognition extremely difficult. It is by no means self-evident that registration would be granted to afforestation requests. The UNFCCC requires tough standards for additionality. New plantings must sequester more carbon than pre-existing baseline levels. Most of Israel's areas that are appropriate for future afforestation are either already planted or have already been designated as forests, disqualifying them under the additionality criterion. Forest maintenance does not qualify for credits. Neither will the UNFCC allow credits for reforested trees planted before 1989, or afforested trees planted during the past 50 years.

Additionality does not imply that afforestation projects were never previously conceived or planned prior to the CDM certification process. For instance, the aforementioned Guangxi River Valley afforestation and reforestation project was included in China's theoretical national reforestation plan. However, the Chinese applicants were able to demonstrate that the plan lacked the requisite political willpower and funding and would never have been undertaken were it not for the financial incentives associated with carbon credits. The low likelihood that the valley would actually be reforested without CDM certification conferred on it additionality status (UNFCCC 2006).

In the case of Israel, the KKL intends to plant the remaining 30,000 ha of land zoned for forests under National Master Plan 22. It would be difficult to argue in favor of additional carbon reductions on land that over the next 20 years is already scheduled to be afforested. If other open spaces could be identified and land-use rezoned for forests, then the project could legitimately argue the existence of additionality. But given the influence of Israel's vigilant environmental movement, which opposes designating much smaller tracks of land for solar energy projects, this hurdle should not be underestimated.

A further obstacle concerns scale of planting. Large-scale projects, which may be implemented by any company or organization, are those that sequester more than 8000 tons of carbon dioxide (CO_2) per year, on average, over the project's first five years (UNFCCC-c 2009). If a hectare of new dryland forest, comparable to Yatir, can sequester an average of 2.5 tonnes of carbon per year, 3200 additional hectares must be planted to reach the minimum average 8000 tons/year. This is twice the amount of new forest typically planted annually in Israel. The CDM system is not open to protracted implementation of such plans. And the 3000 or even 2000 ha are presently unavailable for dense forest plantings.

Small-scale afforestation projects are undoubtedly more promising for diminutive countries like Israel. Under UN criteria, these stands may sequester any amount that project developers consider financially lucrative, but they must be developed or implemented by low-income individuals or communities (UNFCCC-c 2009). During recent years there is growing involvement in KKL forestry by indigenous, semi-nomadic Bedouin populations of Israel's Negev desert who surely qualify as Israel's poorest ethnic group (Swirski and Hasson 2006). For instance, the chief forester in Yatir is a Bedouin and 65% of Bedouin grazing take place in KKL forests. Establishing a partnership in which Bedouin lease forest land may be feasible. Other, Jewish low-income communities might also be eligible for such projects. But given the high costs of registration and meeting monitoring requirements, it is unlikely that the capacity or the resources exist to launch such an initiative.

A further constraint is that forests are narrowly defined under the UN rules and must have a crown cover of 10–30% or equivalent stocking level (Enderlin 2007). This density is met by the traditional KKL conifer plantings in Yatir and the Biriya forests. However, this canopy cover does not exist in many of Israel's newer, semi-arid stands where management plans call for low-density 'savannization' type of woodlands.

Economic Considerations

The costs of certification are considerable. In 2004, the World Bank's Carbon Finance Business estimated an expense of $100,000 for up-front transaction costs for project design document preparation, negotiation, and validation: $20,000 in verification costs for 7 years, based on a discount rate of 12% (World Bank 2004). This price appears stable. Market prices of carbon credits based on afforestation and reforestation tend to be far lower than for other carbon reduction projects. This is partly because questions remain about whether afforestation is an acceptable 'carbon' commodity. Planting trees has been excluded from the European Emissions Trading

System (Kruger and Pizer 2004). As trees may die or burn, the carbon sequestered is not considered to be *permanent*, nor is any achievement deemed final relatiuve to other CDM options. Accordingly, for afforestation and reforestation CDM projects, the project implementers may choose between a fixed 30-year crediting period and a 20-year period that may be renewed twice. This makes CDM credits for afforestation inherently less valuable on the market than alternative Kyoto offsets, but in some cases may allow for smaller-area plantings to be financially viable.

In Israel's case, profitability appears to be particularly dubious, because economies of scale would never be large. Even if markets for CDM *Certified Emission Reduction* credits (CERs) for forestry remained steady at $US 3-7/t$CO_2$e (ton of carbon dioxide equivalent removed), the associated costs of registration and monitoring would be prohibitive for the relatively small stands that make up Israel's forests. Best-case-scenario internal calculations suggest that a comparatively large forest stand of 2000 ha would only begin to break even after five years, in terms of recouping planting costs and covering the $100,000 registration outlay. Potential losses due to pests or fire worsen the equation. These calculations do not include positive externalities associated with expanding recreational sites, habitats and rangelands. If the market price of forestry CERs were to increase, then the cost-benefit ratio would improve accordingly. It is unlikely, however that meaningful profits would be made sequestering carbon on Israel's limited available land.

Low profitability was recently confirmed in doctoral research in which carbon yields were simulated by means of the CO2FIX v3.1 model for *Pinus halepensis* across Israel's steep rain gradient (Rueff 2009). Wheat and pasture yields were also predicted using 30 years of weather data to simulate moisture stress. The projections indicate that at present prices, despite high anticipated levels of sequestration in dry-subhumid regions, carbon trading by afforesting would generate a lower return than an alternate investment of wheat planting on the same land.

The economic calculus changes when annual precipitation drops to below 400 mm, because of the inherent volatility of wheat production in an area with dramatic local fluctuations in rainfall. Because trees have no difficulty surviving the drought years, their more modest return is far more reliable. In short, opportunity costs decrease along the rainfall gradient. Ultimately, the study concluded that carbon prices will have to rise considerably before most productive drylands giving the highest carbon yields become worth afforesting, especially considering wheat prices may also rise.

Ethical and Administrative Considerations

Carbon sequestration through tree-planting is highly controversial and critics have raised several 'principled' objections to its utilization (Lohmann 2006; Takacs 2009; Van Kooten et al. 2007). Among the key problems that were raised by Israeli decision-makers were:

Rationalization of Inactivity

This criticism is broad, going to the essence of environmental 'trading' dynamics. Sequestering carbon, it is argued, substitutes for necessary reductions in carbon emissions from fossil fuels without contributing to production of clean energy or development of clean energy technologies. The phenomenon has been satirized in the web-site: www.cheatneutral.com. The site contains fictitious testimonials from individuals who implicitly compare the carbon market to their romantic lives where they cheat on their partners, but pay other couples to remain faithful in their stead, thus maintaining an illusion of fidelity. Planting trees, presumably, gives the public a 'feel good' excuse for avoiding hard decisions and lifestyle changes that greenhouse gas reductions require. This argument is particularly compelling in Israel which for 17 years has evaded embracing an Annex I, developed country status, despite its $US 28,000 per-capita GNP.

Leakage

Because all climate change policies have a global frame of reference, decision-makers need to be constantly concerned about unanticipated consequences of interventions which may transfer or increase carbon emissions outside the target sector. This phenomenon, known as *leakage,* is of particular concern in projects involving afforestation. If, for example, pastureland is transformed into woodland, farmers may establish pastures elsewhere and clear more productive forests in a different location. In such a case afforestation initiatives may actually produce net increases in greenhouse gases (Murray et al. 2007). To prevent such situations from an effective administrative response is required, but this is easier said then done.

Such emission quantities, for example, should be estimated and deducted from any credits granted. In practice it is impossible for overseeing agencies to know all relevant circumstances and foresee individual decisions. International leakage and market shifting may be even more difficult to project and integrate into registration criteria. For instance, afforestation projects in Israel could conceivably usurp other carbon reduction efforts, by compromising land that could be used for solar energy fields. Ultimately, leakage did not constitute a compelling consideration in Israel's decision-making process.

Accounting

Getting the numbers right is also a daunting administrative challenge. Calculating biological sequestration, especially in trees, is no simple task with estimates varying widely, with no calculation system considered fully reliable. Indeed, highly precise empirical measurements made in Yatir show that there is a great temporal range of sequestration levels among dryland trees. Sequestration rates for dryland forests depend on factors including disturbance of carbon already sequestered in soil, lowered albedo (less light reflected from dark-colored trees than light-colored arid soils) and future tree and soil degradation due to global warming itself.

Then there is the question of what needs to be calculated. Carbon sequestration, while critical, is not the only factor in climate change dynamics. The recent findings Rotenberg and Yakir (2010) suggest that their earlier projections regarding the overall contribution of dryland afforestation to combating global warming may have been overly optimistic. After ten years of monitoring the Yatir forest, their assessment of the total energy budget suggests that it directly absorbs and retains heat beyond their initial expectation. Indeed, Israel's largest semi-arid forest exhibits a cooling system that because of the albedo effect absorbs high levels of solar radiation energy and then retains it through suppression of infrared (thermal) radiation back into the atmosphere. Recently, in separate letters to the journal Science, their evaluation has been criticized as imprecise and pessimistic (Lee 2010; Leu 2010). Unlike more industrial processes, reliable monitoring of such complex phenomena is likely to be prohibitively expensive. For small-sized Israeli sequestration sites, this constitutes a relevant consideration.

Permanence

Carbon sequestration is calculated over the expected tree lifetime. Calculations can fall short when a tree burns or otherwise dies early. For example, the massive forest fires that broke out in 2007 in the Western United States contributed between 4 and 6% of the country's greenhouse gas emissions (Johnson 2008). Had credits been claimed for the planting of such trees, actual atmospheric benefits would have been overstated. In the lifecycle of trees, carbon sequestration is only temporary; the sequestered carbon eventually returns to the atmosphere when the trees dies or decompose. The US Congressional Budget Office has raised several possibilities for addressing this conundrum:

> One method would be to credit biological sequestration projects as carbon was stored and debit them as it was released into the atmosphere. A second approach would be to discount the value attributed to biological sequestration projects based on expectations about the amount and timing of any release of sequestered carbon into the atmosphere. A third approach would be to treat CO_2 credits associated with biological sequestration projects as though they had to be redeemed in the future. Credits could carry expiration dates, at which time they would have to be regenerated by continuing the sequestration project, establishing a new project, or otherwise achieving a permanent reduction in emissions' (US Congressional Budget Office 2007, p. 10).

Such thoughtful ideas for dealing with inherent uncertainties associated with biological sequestration offer reasonable frameworks for programs in the future. Unfortunately, they cannot solve a forestry agency or individual firm's dilemma that currently seeks responsible climate change mitigation response. In the case of Israel, where forests face the twin risks of pests and arson, the question of permanence is highly relevant.

Ecological Considerations: Available Open Space and Biodiversity

Carbon sequestration through afforestation requires large areas of land. The United Kingdom, over 20 times the size of Israel, reported that its entire forest estate, which covers 12% of the countryside, only contains carbon quantities commensurate to national emissions during a single year from fossil-fuel burning (Broadmeadow and Matthew 2003). For Israel, with its high population density, the contribution of carbon sequestration will quickly run up against compelling geographical constraints. Additional afforestation projects have to go through a formal approval process in Israel's planning system, which can take years, especially if there is public opposition.

While public perceptions of afforestation projects involve renewed ecosystems and net habitat gains, in fact tree plantations frequently involve monocultures which are inhospitable to indigenous plants and animals. Studies suggest that even birds may suffer from an increase in afforestation (Pithon et al. 2005; Matthews et al. 2002; Allan et al. 1996). The impact of new plantings on biodiversity depends largely on local conditions and the kinds of trees planted. In Israel, there is disagreement about whether newly planted woodlands provide valuable habitat or are merely homes to invasive species, reducing the range of indigenous wildlife. Internal sequestration policies need to include specific directives for maximizing biodiversity and social benefits.

Ultimately, the most compelling argument posed by opponents to biological sequestration is that CDM projects or expanded reliance on afforestation offsets in national inventories supplant more effective forms of carbon offsetting. After reviewing the case against biological sequestration programs, Canada's noted environmental commentator David Suzuki, offered an implicit threat of public relations fiascos for companies who seek afforestation carbon credits.

Israel's Voluntary Offsetting Approach

Faced with considerable legal and logistical hurdles in attaining UN accreditation, a dubious cost-effectiveness equation and considerable philosophical and ecological quandaries, Israel chose not to package future afforestation efforts as formally registered CDM projects that could then be marketed. The potential economic gain, if it exists at all, did not justify the price in terms of paperwork, possible institutional integrity or environmental credibility. Rather, voluntary offsetting through support for Israeli tree planting offered a more compelling alternative.

Voluntary carbon offsets do not purport to make calculated reductions in atmospheric greenhouse gas concentrations. Rather, voluntary programs enable the public to support projects that are environmentally positive and which contribute to reduced carbon emissions. Frequently, these programs involve an interactive, educational process where individuals, businesses and organizations calculate the carbon emitted by their travel, electricity, heating and other activities, purchasing credits to offset these emissions (Novey 2007). Credits purchased are not regulated by the UN or any other body, although rating systems, of varying credibility, have emerged (Gies 2006).

Typically, voluntary offsets support three types of investments:

1. *New technology development* contributions to the development of clean technologies that would not otherwise be developed as quickly or at all.

2. *Current clean energy production* contributions offsetting individual use of fossil fuels by paying for someone else's use of clean technologies. Alternately, participants pay to capture equivalent amounts of carbon from other emitters, such as landfills or cattle farms.
3. *Carbon sequestration* contributions covering expansion of carbon sinks, most commonly through afforestation or reforestation.

It can be argued that no less important than the actual reduction in greenhouse gases associated with voluntary offsets, is the educational process and heightened awareness engendered among the participating public.

The KKL selected the third alternative in its voluntary approach, launching an informal offsetting initiative designed to support new KKL tree plantings. The program was both a fundraising gimmick and an educational tool. Offset purchases are primarily facilitated through web-based calculators—one international (http://www.elysium.co.il/kakal/cc.html) and one specifically designed for the US market (http://support.jnf.org/goneutral/carbonCalc.html). Individuals calculate on-line individual carbon emissions and are then directed to a web-page where they can purchase the requisite number of trees to 'go neutral', using a credit card or other payment form.

Critics can argue that the voluntary offset initiative does little to push individuals towards source reduction; voluntary offsetting thus indirectly perpetuates environmentally destructive conduct. Yet, presumably, the act of calculating the magnitude of individual carbon emissions and quantifying costs is an important stage in a process where the public becomes personally accountable for otherwise diffuse and amorphous global climate changes. Additional funds for worthy forestry projects are ultimately a positive thing. While surely trees are not a panacea for Israel as it seeks to impose significant carbon reductions on economic activities and meeting international responsibilities, they are part of the solution.

Conclusions

Israeli forests, largely located in drylands, have transformed the country's landscape, providing recreational and ecological services, and are cherished by the local public. Initial hopes for a prosperous timber industry appear to have been ill-advised. Pervasive water scarcity and poor soils have been simply overwhelming. Israeli forests will continue to provide recreational opportunities for millions of Israelis and offer habitats to wildlife. Only recently has the ability of tree growing to contribute to the local economy been reconsidered. While experience with fast-growing eucalypt trees contributed reasonably to the local lumber market, it is unlikely that the traditional focus of forestry programs will change.

With the emergence of world carbon markets pursuant to the Kyoto Protocol and CDM projects' economic potential, it is only natural that carbon sequestration through afforestation be assessed as a for-profit enterprise. At present, tree-planting for carbon does not constitute a meaningful economic opportunity for Israel. The main factors which undermined initial enthusiasm for transforming traditional tree-planting activities into a carbon asset on world markets include the UN's additionality criterion, space constraints on plantation establishment, the ephemeral nature of biological sequestration and questionable profitability. Further, in that the KKL, Israel's forestry agency defines itself as a 'green organization', many principled objections to forestry CDMs resonated among its leadership.

The establishment of thousands of forest stands on previously degraded soils offers an interesting case study in combating desertification which may be valuable to other dryland nations considering aggressive afforestation programs. At present, it does not seem that the next chapter in the Israeli afforestation narrative will be driven by global efforts to reduce atmospheric greenhouse gas concentrations. But, given the high sequestration rates of conifers, even in semi-arid climates, other country's which do not face these constraints may find that dryland afforestation generates a profitable commodity in the world's carbon market (Perez et al. 2007). As Israel begins to consider a new status as an Annex 1 developed country and its associated responsibilities for reducing carbon emissions, afforestation can and probably should become integrated as a small part of its national carbon reduction action plan.

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