Challenges of translating science into practice: poplars and other species in the Three North Region of China

J. Carle and Q. Ma

A ten-year project to combat desertification, mainly with poplars, produced comprehensive technical knowledge, but applying it on a larger scale remains a challenge.

Jim Carle is Senior Forestry Officer (Plantations and Protection) in the Forest Resources Division, and **Qiang Ma** is Forestry Officer (Econometrics) in the Forest Products and Economics Division, FAO Forestry Department, Rome.

The destruction of the natural vegetation cover of the Korqin Sandy Lands, in the eastern part of the Three North Region of China, began about a thousand years ago. Gradual desertification, caused mainly by human activities (overgrazing, wood cutting, shifting agriculture and tillage agriculture on sandy lands), has been accelerating since the twentieth century (see Figure). Very strong winds, which occur about 25 to 40 days per year, mainly in spring and winter, are the chief agents of desertification and are normally associated with the generation of dust storms.

The population of the area is a mix of Chinese, Mongolian, Manchurian and other ethnic minorities. Population densities have increased from 30 people per square kilometre in the 1950s to 51 per square kilometre in 2000. About 70 percent of rural income is based on agriculture (maize, legumes and rice on waterlogged lowlands) and 30 percent on animal husbandry (goats, sheep, cattle, pigs, geese and poultry) (State Forestry Administration of China, Belgium Development Cooperation and FAO, 2002).

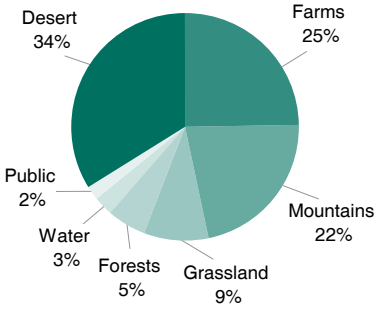
The Chinese Government recognized that to maintain crop and livestock productivity and the livelihoods of expanding communities, it was essential to integrate forests and trees for shelter and shade with improved agriculture and livestock management in the landscape. Within China's extensive programme for protection against desertification in the Three North Region, a project that assisted afforestation in the Korqin Sandy Lands was carried out from 1991 to 2002.

At the outset of the project, the remaining natural vegetation in the Korqin Sandy Lands comprised sparsely wooded shrub grassland with relicts of poplar (*Populus simonii*), willow (*Salix matsudana*, *Salix gordejevii*), wild peach (*Prunus armeniaca*), elm (*Ulmus pumila*) and other woody species. The project initiated large-scale plantations of drought-tolerant and cold-resistant species – not only *Pinus sylvestris* var. *mongolica*, which had been widely established in the 1960s and 1970s, but increasingly the indigenous *Populus simonii*, which previously had been almost ignored (State Forestry Administration of China, Belgium Development Cooperation and FAO, 2002).

THREE NORTH SHELTERBELT PROGRAMME

Beginning in 1978, the Chinese Government, through the Three North Shelterbelt Programme, established an extensive network of shelterbelts and plantation forests (the "Great Green Wall") across northern China, with the objective of

Land use in the Korqin Sandy Lands



Source: State Forestry Administration of China, Belgium Development Cooperation and FAO, 2002.

E. DE LAETHAUWER

The project demonstrated land-use systems integrating tree, shrub, pasture and cash crops in agroforestry systems: intercropping of poplars, maize and legumes, Tong Yu District

protecting agricultural and pastoral lands, as well as human settlements, from wind and water erosion. This programme proposed to plant shelterbelts and restore landscapes over 4.06 million square kilometres (of which 1.33 million square kilometres were desert lands) or 42 percent of the country's area, which supports 170 million primarily rural, farm-based people (about 10 percent of the national population). The Three North Shelterbelt Programme objectives are to improve the soil and water conservation of the Three North Region, to moderate the effect of strong winds and desertification through increased forest and vegetation cover, and to enlarge the limited resource base for the increased production of industrial wood supplies and fuelwood to meet current and future wood requirements.

By 1991, the Three North Shelterbelt Programme had established an estimated 20 million hectares of tree plantations, predominantly poplar hybrids, through planting or aerial seeding. However, survival, growth, yields and protection of adjoining agricultural lands did not meet expectations because of poor site, species, provenance and clone matching; limited genetic diversity in large-scale plantings; and poor nursery, site preparation, establishment, maintenance, silviculture and protection practices (State Forestry Administration of China, Belgium Development Cooperation and FAO, 2002). Because of these adverse factors, aggravated by the narrow genetic base of the poplar hybrids used, plantings were susceptible to attack by insect pests (e.g. Asian longhorn beetle) and diseases (e.g. Melampsora rust), and survival and production tended to be low.

REHABILITATION OF THE KORQIN SANDY LANDS

Aware that ample scope existed to improve plantations through new species and clones, tree breeding and superior nursery and establishment techniques, including mechanized methods (State Forestry Administration of China, Belgium Development Cooperation and FAO, 2002), the Governments of China and Belgium funded the project "Afforestation, Forestry Research, Planning and Development in the Three North Region", targeting the Korqin Sandy Lands. The development objective of the project was to enhance soil and water conservation to improve the socio-economic well-being of the population living in the area by increasing and managing, in a sustainable manner, the amount of forest products and other services while ensuring that the environment was protected. The project, carried out from 1991 to 2002 with technical assistance from FAO, was executed by the State Forestry Administration and implemented through the Three North Bureau, with scientific collaboration from the Chinese Academy of Forestry and Beijing Forestry University.

Project activities were concentrated in Naiman Banner[1] (Inner Mongolia Autonomous Region), Tongyu County (Jilin Province), Jinxian (or Linghai) and Zhangwu Counties (Liaoning Province), with headquarters in Tongliao (see Map). Field activities were undertaken through local forest research institutes, forest farms and local communities (FAO, 1996, 2000).

This ambitious project had five integrated components: tree improvement and breeding, afforestation research, mechanized afforestation, project coordination and management, and training.

The project advanced from conventional poplar afforestation to revegetation and restoration of the typically degraded sites of Korqin, promoting integration of forestry, agriculture and animal husbandry for sustainable livelihoods and landscape management. The project demonstrated land-use systems integrating tree, shrub, pasture and cash crops in agroforestry systems combined with horticulture and viticulture, including greenhouses

[1] A banner is the county-level administrative unit in Inner Mongolia.

Korqin Sandy Lands project area

on the leeward side of sand dunes. It developed shelterbelt designs including the use of tree and shrub species to provide fodder for grazing animals, most important for the local economy and for the protection of the local environment. Models were established using shrubs as fences and hedgerows around and in pastureland and using shelterbelts to reduce wind erosion and to implement controlled rotational grazing. The project also tested establishment of fencing to exclude roaming animals during critical establishment periods, as well as reduced tillage and retention of crop stubble (particularly maize) to reduce wind erosion and improve soil fertility. Local herdsmen and farmers were consulted and involved in the design, planning, preparation and implementation of the agroforestry models. Wind erosion in demonstration areas was thus reduced by 75 percent in comparison with adjoining lands (State Forestry Administration of China, Belgium Development Cooperation and FAO, 2002).

Poplar improvement and breeding

The project prepared a long-term breeding plan for poplars, using as the basis a medium-sized provenance collection of *P. simonii* and some related species plus imported provenances of *P. deltoides* and *P. nigra*. In addition, the clonal banks incorporated many of the existing poplar varieties of northeast China together with some imported varieties, and comparative studies were begun on their behaviour and growth. A large collection of poplar clonal material was made and planted out, with the emphasis moving away from production forest to shelterbelt forest (FAO, 1996). From 49 afforestation trials, encouraging progress was made towards defining the requirements for cheap and effective deep planting of poplars, making use of unrooted planting stock without irrigation in shelterbelt conditions.

Poplar introduction and improvement activities included *ex situ* conservation of *P. simonii*, which involved reconnaissance and sampling of the natural distribution area of the species in northeast, northwest and north central China. About 500 genotypes were identified and cuttings and seeds were collected and included in the *P. simonii* gene bank at the Xinglongzao Forest Farm. Other indigenous poplar species such as *P. pseudosimonii* and selected native and exotic poplar species, including *P. deltoides*, *P. trichocarpa*, *P. nigra* and *P. ussuriensis*, were also incorporated.

The project raised awareness of the need for *in situ* conservation of *P. simonii* by protecting trees surviving throughout northern and central China, in order to conserve the valuable full genetic variation of the species. Especially after three successive years of exceptionally dry weather (1989 to 2001) in the Korqin Sandy Lands, when annual rainfall was 190 to 300 mm (about half of normal), and after the severe winter of 2001 (when temperatures fell to –41°C), the superiority of this species in extreme conditions was clearly evident.

Between 1991 and 2001, the project out-planted 532 Chinese clones and 120 introduced clones (from France, Belgium and Canada) in clonal banks for gene conservation and exchange and for introduction in the Three North Region. Independent collections by the Chinese Academy of Forestry were also replicated in these clonal banks. Superior clones were screened for their adapatation to different types of sites to be reforested, based on the criteria of survival rate, growth in nursery, root development, growth in the field, resistance to harsh conditions (drought and frost) and resistance to pest and diseases. Larger-scale propagation was undertaken for these clones to ensure the availability of planting stock for further distribution and for pilot plantation development.

A tree breeding strategy and programme was elaborated in the Long-Term Poplar Improvement Programme to create and introduce completely new clones, obtained through controlled pollination of poplar species with desirable

characteristics. The main species used in such hybridization work were *P. simonii*, *P. nigra*, *P. deltoides* and *P. cathayana*. The objective of the breeding programme was to create new clones with resistance to early autumn frosts; frost tolerance in winter; resistance to droughts and sudden temperature changes in spring; a well-developed root system ensuring a survival rate in the field of over 90 percent; better than average pest and disease resistance; cylindrical, straight trunks with small branches; and ability to take up available water and nutrients. The project carried out 219 inter- and intraspecific crosses, of which 147 were successful; the progeny were raised in the nursery and planted out. Through this work, thousands of new, potentially valuable clones were rigorously evaluated for outstanding characteristics.

Stands of the new clones were established in the field to conserve these valuable genetic materials and to test long-term performance (over at least 10 to 15 years) against established selection criteria (FAO, 2000).

Afforestation and mechanization research

In addition to the work on poplars, the project also established a conifer introduction, selection and afforestation programme to explore the possibility of using other species besides the indigenous *Pinus sylvestris* var. *mongolica*, which was prone to attack by moths, *Dendrolimus* spp. Trials were established to test 14 provenances of *P. sylvestris* var. *mongolica* and 21 other coniferous species, including the promising species *Pinus banksiana* and *Pinus sylvestris* var. *sylvestriformis*. Nursery techniques were tested to evaluate the merits of root pruning of bare-rooted stock, use of root trainers for containerized stock, micro-irrigation and various timing and age of planting of *Pinus* seedlings. Demonstration areas of 2 000 ha of *P. sylvestris* var. *mongolica* were established.

The project also evaluated broad-leaved species to identify alternatives to monocultures of poplars and pines, which were prone to attack by pests and diseases. Increased diversity of species in the stands and diversification of the production base through the introduction of broad-leaved trees and other shrub and fodder species with the conifers were deemed essential for sustainable land use. The project distributed seedlings of over 40 different broad-leaved species, both indigenous and introduced, to researchers in the area, and 20 of these species were tested in the field.

The project included research in poplar nursery techniques and lower-cost mechanized establishment techniques, including development of nursery stock and planting systems suitable for mechanization; timing and depth treatments for unrooted stock used in deep planting; and mechanized deep planting techniques to improve survival and growth without irrigation in extreme drought conditions. The project designed and manufactured mechanized equipment such as an auger planter and a medium-depth planter for poplars and a root pruner for pine nurseries. The State Forest Administration endorsed the various techniques, equipment and technical and financial models for wider application to afforestation in northern China (FAO, 2004).

Using soil and site classification maps, alternative afforestation models were developed based on results from the research trials and demonstrations, including a range of mechanisms involving forests, trees and shrubs and agroforestry systems. Financial analyses were conducted on each of the afforestation and revegetation models to test viability and sensitivity of internal rates of return to changed work norm produc-

E. DELAETHAUWER

Poplars protect greenhouses established on the leeward side of sand dunes for grape production

tivities, costs and prices. The technical and financial models, which reflected the most successful demonstrations in the field, proved valuable planning and decision-making tools (FAO, 2004).

Project coordination and management

The project established computer databases for efficient access and processing of information on research trials, poplar clones, weather and project equipment and vehicles. It set up links between the Chinese Academy of Forestry and Beijing Forestry University for future joint research and development in poplar breeding and mechanized afforestation.

The project also developed and demonstrated new site planning and management techniques (nursery, site preparation, establishment and tending) for poplars, pines and other broad-leaved and coniferous species. Land use and site classification systems and maps were prepared to advance understanding of the desertification process and restoration practices required to combat it (State Forestry Administration of China, Belgium Development Cooperation and FAO, 2002). Knowledge of water tables, soil nutrients, slope and aspect, vegetation and human disturbance proved useful not only for planning afforestation and revegetation activities, but also for all local stakeholders involved in land use and rural development.

Training

In-service training, study tours and fellowships were an important and integral component of the project. In-service training was conducted in English language, computer use, tree breeding, pest and disease control, use of forest machinery, forest management, soil analysis, experimental design, cost determination and analysis, forest economics, land-use classification and site class classification. Twelve international fellowships provided training opportunities for Chinese professionals in France, Belgium, the United Kingdom and the United States, in such technical areas as mechanization, tree breeding and improvement, afforestation and nursery techniques. Furthermore, three national fellowships were arranged in economics at Beijing Forestry University. In addition to a series of study tours in northern China, 40 Chinese employees visited Belgium, France, Italy, the Netherlands, New Zealand, Israel, Australia, Canada and the United States to establish professional contacts, make field visits, collect reproductive materials and participate in two-way transfer of knowledge and technology. Whenever appropriate, project personnel were sponsored to attend national and international conferences. The project published numerous scientific papers, technical publications and information materials to increase public awareness.

TRANSLATING RESEARCH INTO DEVELOPMENT

At the outset of the project, the principal afforestation investors, and thus the clients of the project, were the State-owned forest farms. However, as in other regions of China, farmers, families and smallholders in afforestation and agroforestry systems became involved because of their interest in protecting their agriculture and livestock investments and diversifying their incomes in the wake of the economic reforms of the 1980s and 1990s, which gave increasing responsibility to farmers. In combining various activities involving forests, trees, shrubs, improved pastures and food crops in the landscape, the project needed to engage with communities, farmers and other stakeholders so as to understand their livelihood needs and aspirations. This was necessary not only in demonstrating and adapting techniques from the project and farmers' traditional practices, but also in developing feasible afforestation models and financial

E. DE LAETHAUWER

Evaluation and planning at project headquarters in Tongliao, Naiman Banner

E. DE LAETHAUWER

Former desert stabilized by poplars under the project to rehabilitate the Korqin Sandy Lands, Tong Yu District of Mongolia

analyses. Research, demonstration, extension and outreach programmes needed to be rethought in terms of the needs of local communities.

The planning, technical and financial tools and the mechanized equipment developed by the project are all interesting individually. However, they need to be considered as integral parts of a series of interrelated tools for afforestation and revegetation which can be used to achieve major benefits to all stakeholders involved in combating desertification and rehabilitating degraded lands in the Three North Region. Combined, these tools can allow investors, policymakers, planners and managers to relate specific sites, characterized using the land classification system, to specific species adapted to the sites and to appropriate technical models, which provide a basis for evaluating potential yield and productivity, which in turn provides the basis for financial analysis.

The tools can assist national policymakers and planners to prioritize lands and sites for particular types of afforestation and revegetation. Calculating potential financial returns will allow identification of types of investors who may contribute to afforestation or revegetation on particular classes of land. If the financial returns for particular sites and technical models are attractive, the State may consider encouraging the private sector (corporate or smallholder) to invest in planting on these sites, encouraging them to adopt the genetic and tree improvement methods and equipment demonstrated by the project. If certain sites, technical models and financial returns are not sufficiently attractive for private enterprise, the State may consider direct or indirect incentives (financial or otherwise) to encourage investors. On other sites, for example those that demonstrate severe environmental degradation, where the technical models and financial returns are not attractive to the private sector, afforestation and revegetation may still be warranted under a State funding programme to ensure environmental, social and wider economic benefits (shelter, harnessing of moving sands, etc.). Thus, the tools developed by the project can have a critical policy and strategic planning function.

There is also sufficient information available for the Three North Bureau and the private sector not only to adopt technical models but also to apply particular technology (nursery management systems, tools and methods for mechanized site preparation, etc.) to increase survival, growth and yields. Private companies may wish to adopt more technically complex and capital-intensive techniques, while smallholder investors may choose options requiring lower investment. In this instance, the tools can contribute to investment, operational planning and implementation of afforestation and revegetation.

Research is never complete, and the more scientists know about afforestation and revegetation of the Three North Region, the more they realize they need to know. Scientists also learn from partial outcomes that are yet to be followed up and monitored. In this instance the tools provide an incomplete but important picture to be supplemented and refined

in the future through further research and development.

Any new knowledge and technology needs to be integrated into the education, training and extension programmes of the forestry and agroforestry sectors. In addition to the capacity building provided by the project, dissemination of information and its incorporation into curricula and practical learning fulfils critical education, training and extension functions.

Some of the important principles and practices that were derived through the project may not be directly applicable to other areas in China, but the methodologies can point to similar research, demonstration and application methods. In this instance the tools have an important demonstration function.

CONCLUSION

The Korqin Sandy Lands of the Three North Region have excellent potential for afforestation and revegetation using flexible mechanisms to support also livestock and cash crop productivity and thus the livelihoods of rural people. The project has made available mechanized equipment, planning, technical and financial tools and information from soundly based research and demonstration. A significant number of people within the Three North Bureau, counties and institutes have been trained (in-country and abroad). The ecological zone in which the Korqin Sandy Lands are located has been identified as a priority area for combating desertification, and there are potential investors. However, investment in applying the new knowledge and technology has not yet occurred to the levels anticipated. Although potential private investors (particularly smallholders) have demonstrated a strong interest in the outputs of the project, they have been reluctant to take full advantage of the opportunities because of the risks of investing in long-term afforestation and a lack of development funds.

The Chinese Government is addressing the major challenges to provide a sound enabling environment for investment. These include:

- a stable, clear and consistent policy, legal and regulatory framework to help farmers have the confidence to invest in forests and trees to diversify their land use and benefit from doing so – particularly relating to land and crop tenure rights and rights to manage, harvest, transport and market crops (including wood);
- decentralization and further strengthening of the capacity of provincial and county officers and research and training institutes to integrate the new planning, scientific and mechanical tools into technical and extension services to transfer knowledge and technology to the primary beneficiaries, particularly smallholders;
- securing development funds from international agencies and attracting public and private (corporate and smallholder) investors.

The government and major multilateral and bilateral donors are together seeking to address these critical issues to ensure that afforestation and revegetation can be effective in combating desertification in the Korqin Sandy Lands. ◆

Bibliography

FAO. 1996. *Report of the Terminal Evaluation Mission, GCP/CPR/009/BEL Phase I.* Bangkok, Thailand.

FAO. 2000. *Report of the Mid-Term Evaluation Mission, GCP/CPR/009/BEL Phase II.* Bangkok, Thailand.

FAO. 2004. *Terminal Evaluation Mission, GCP/CPR/009/BEL, Phase II.* Beijing, China.

State Forestry Administration of China, Belgium Development Cooperation & FAO. 2002. *Afforestation, forestry research, planning and development in the Three-North Region of China (FAO/GCP/CPR/009/BEL) – technical project review document (1990–2002).* Tongliao, China. ◆