In 2003, the CGIAR Secretariat asked the Standing Panel on Impact Assessment (SPIA) to initiate a series of impact assessment studies on natural resources management (NRM) research. The main objectives of this SPIA initiative were to obtain better information on the demonstrable impacts of CGIAR investments in NRM research, to identify gaps in data and methodology, and to provide avenues for better NRM impact assessment in the future. The impact brief presented here describes the major results of one of seven center NRM impact assessments emerging from this SPIA initiative: Shideed K., Alary V., Laamari A., Nefzaoui A., and El Mourid M. Forthcoming. NRM technologies in crop–livestock production systems in arid and semi-arid areas of Morocco and Tunisia. In: *The Impact of Natural Resource Management Research: Studies from the CGIAR* (Zilberman D. and Waibel H., Eds). CAB International: Wallingford, UK.

SCIENCE COUNCIL
CGIAR

SCIENCE COUNCIL BRIEF

STANDING PANEL ON IMPACT ASSESSMENT

NUMBER 12


ICARDA

Nourishing the Future through Scientific Excellence

Fighting Land Degradation in the Drylands: NRM Technologies for Crop–Livestock Farming

A tragedy of the commons is unfolding in the rangelands of West Asia and North Africa (WANA), where land is either public or collectively owned. Overgrazing under this land tenure has led to severe land degradation and soil erosion.

Poverty and environmental degradation are intertwined in this low-rainfall region, where more than 38 million people live in rural areas and depend mainly on agriculture. Traditional rangeland grazing provides fodder in winter and spring, while in summer and autumn the animals browse cereal stubble and other crop residues. But rangeland feed resources have shrunk from providing 70 per cent of animal feed requirements five decades ago to no more than 25 per cent today. This is mainly because there are more animals but also because of inappropriate land-use policies and lack of secure property rights, all of which fuel unsustainable land use.

To stem the degradation, the International Center for Agricultural Research in the Dry Areas (ICARDA) and national partners in Morocco and Tunisia have designed alley cropping technologies that enhance fodder quality and quantity, thereby reducing pressure on the rangelands. The technologies were introduced on marginal lands in the two countries through the Mashreq/Maghreb (M&M) adaptive research project, which combined research on NRM with research on integrated crop–livestock production.

Towards better crop–livestock systems

Integrated crop–livestock systems are predominant in much of WANA. In these systems, most household income comes from sheep and goats. The technologies introduced by the M&M project increase dry-season fodder for these small ruminants while also reducing soil erosion.

In Tunisia, the project introduced *Opuntia* (spineless cactus) as an alley crop and, in Morocco, *Atriplex* (saltbush). In central Tunisia the project worked with the Zoghmar community, who live in drylands with less than 350 mm of annual rainfall and periodic droughts. In Morocco the study area was Irzaine, in Oujda province. Both areas are characterized by poor soils and shifting cultivation in a traditional barley–fallow system that is rapidly becoming unsustainable.

Opuntia and *Atriplex* are valuable fodder shrubs that are well adapted to difficult dryland climates and soils, serving as a buffer against seasonal fluctuations in the availability of other feeds. *Opuntia* is high in energy, while *Atriplex* is a useful protein supplement. Both shrubs offer additional benefits, providing fuelwood and helping to control erosion. In both the project areas the shrubs were introduced in an alley cropping system, in which they are planted in rows with a cereal crop or pasture species in between.

Methodology

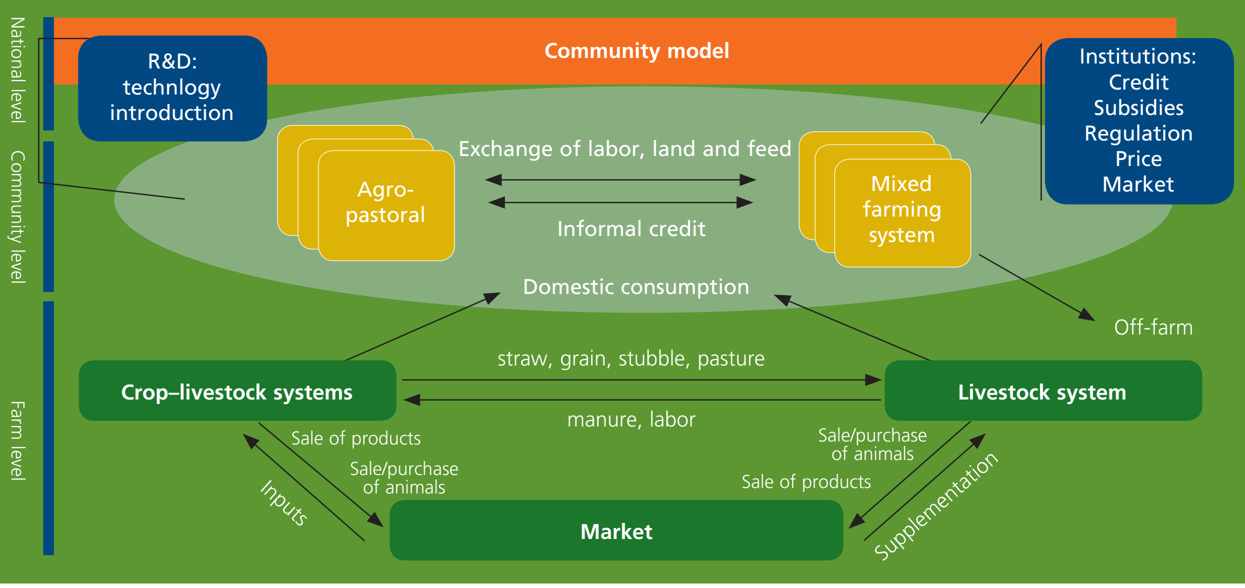
The M&M project assessed the contribution of *Opuntia* and *Atriplex* alley cropping to raising farmers' incomes and reducing poverty. It also gauged the efficiency of the research and development (R&D) investment by ICARDA and national partners.

The project had two phases. Phase I (1995–1998) used participatory methods in farmer-managed field trials whose main purpose was to assess the appeal of the system to farmers as a source of animal feed. In Phase II (1999–2002), the project shifted its focus to integrated natural resource management (INRM). Besides helping farmers to grow more fodder, the project also gathered and analyzed data on the agronomy and ecology of the new alley-cropping technologies.

Researchers in both countries used cost–benefit analysis to study the profitability of investing in alley cropping, and econometric analysis to explore a range of adoption scenarios, including the role of subsidies in promoting these technologies in marginal areas. This approach is a formal method for evaluating subsidies when markets do not set a value on environmental benefits. In Morocco, the project provided an in-kind subsidy to farmers for land preparation, transplants, irrigation during the first year, and labor. In Tunisia, scenarios with and without subsidies were modeled, but no subsidy was actually provided to farmers.

Quantifying NRM impacts often requires researchers to go beyond the farm level to the complex socioeconomic, biophysical, and environmental conditions at community level. It also requires the integration of different temporal and spatial scales. The model used in the Tunisian study met both these requirements, reflecting the complexity of activities at farm and community level, the individual technical and socio-economic constraints that limit or condition adoption, and the universal constraints due to social or economic factors (see Figure 1). This model was also used to validate empirical observations on adoption.

Figure 1. Structure of the community model



For Morocco, a biophysical simulation model called Soil Change Under Agroforestry (SCUAF) was used to assess the biophysical and economic impact of *Atriplex*. The model was calibrated using data from field trials and farm household surveys of both the traditional barley farming system and the newly introduced *Atriplex* alley cropping system in selected communities. SCUAF's biophysical module provided yield and erosion outcomes for both cropping systems. These results were combined with a simple economic module to generate net revenues over time.

Subsidies boost adoption

The effects of the technology on productivity were impressive. Biomass yields in *Opuntia* alley cropping systems in Tunisia increased by 57 per cent over yields in a traditional barley cropping system. This was because of higher grain and straw yields of barley, in addition to cactus pads and fruits. The cactus did not have any adverse effects on the barley and the increased fodder supply reduced costs by 13 per cent. On natural rangelands, the average herbaceous biomass yield increased to an estimated 4.98 t/ha, compared with less than 3.3 t/ha without cactus. The cactus created a microenvironment by acting as a windbreak and increasing soil moisture. It also provided a safe harbor for seeds, thereby nurturing valuable herbaceous fodder species.

The adoption of *Opuntia* alley cropping was measured using two indicators: the proportion of adopters in the total population (adoption rate) and the total area under the new technology relative to the total potential area (adoption degree).

In 2002, the adoption rate was slightly above 30 per cent and the adoption degree was 29 per cent (see Table 1). Adoption increased with farm and flock size: farmers with good land, access to water, and stable off-farm incomes were more likely to adopt the technology than the less well endowed. However, farmers without animals also adopted the technology, attracted by new market opportunities and subsidies. Most of these adopters were small-scale farmers who had lost their animals in the drought 1998–2002.

Similar results were obtained for Morocco. Here the total target area for *Atriplex* alley cropping was nearly 6,290 hectares. By 2003, 24 per cent of this area was under this system. The corresponding adoption rate was 33 per cent, with larger-scale farmers and farmers with livestock again the main adopters.

On average, adopters assigned nearly 27 per cent of their farmland to *Atriplex* alley cropping, but this varied considerably across farms. Overall, the area planted with *Atriplex* increased by 6 per cent annually between 1999 and 2004. Farmers also increased the size of their flocks, since they had more fodder. By 2003 adopters had 25% larger flocks than non-adopters, and paid 33% less for feed than non-adopters. This reduction was due to replacing expensive commercial feeds such as wheat bran and sugarbeet pulp with *Atriplex* biomass and barley straw. *Atriplex* also had environmental benefits, including controlling soil erosion and improv-

Table 1.
Adoption of *Opuntia* alley cropping in Tunisia, by size of farm and flock

Indicators according to farm size			Indicators according to flock size		
Farm size (ha)	Rate of adoption (%)	Degree of adoption (%)	Flock size (heads)	Rate of adoption (%)	Degree of adoption (%)
> 20	61.3	43.2	> 50	46.1	36.8
10–20	41.0	24.6	25–50	38.2	35.3
5–10	34.5	23.5	15–25	36.0	27.0
1–5	12.6	14.5	< 15	25.8	23.0
Landless	0.0	–	0	20.0	21.2
Total	30.6	29.0	Total	30.6	29.0

Source: Farm household surveys, M&M project, ICARDA (2002).[1]

ing soil organic matter, but these could not be evaluated because of lack of data.

The availability of subsidies, farm size, and flock size were the three key determinants of *Atriplex* adoption. Of the three, subsidies had the greatest sway: regression analysis showed the net impact of subsidies was to increase the area under *Atriplex* by 79 per cent.

Cost and benefits

Cost–benefit analysis was used to calculate the financial and economic rate of return to the investment in developing and disseminating *Opuntia* and *Atriplex* alley cropping.

In Tunisia, subsidies made a big difference to the results. The financial internal rate of return (FIRR) to investing in *Opuntia* alley farming for a farmer who received the subsidy was 53 per cent, compared to 17 per cent for a farmer without the subsidy. When the R&D costs for ICARDA and national partners were included, the economic internal rate of return (EIRR) was 16 per cent, assuming that the technology is used on 96,000 hectares after 22 years.

In Morocco, assuming a constant adoption rate at the 2005 level, the estimated IRR was 29 per cent when a time horizon of 2015 was used. The environmental benefits of *Atriplex* alley cropping, such as reduced soil erosion and improved soil organic carbon, were estimated at US$425 per hectare, which is well above the incentive of US$250–300 per hectare provided to farmers by the project. These benefits would have been foregone without the investment in *Atriplex* R&D.

Reflections and lessons

Unlike the patterns typically seen in areas of high agricultural production, the adoption of new technologies in marginal lands is often low because of the variability of returns to farmers and institutional constraints such as land tenure. Subsidies are therefore necessary to promote technology adoption.

By increasing and stabilizing fodder reserves, *Opuntia* and *Atriplex* alley cropping can help mitigate drought. The technology is therefore an effective strategy for reducing the risks faced by dryland farmers. The benefits are expected to spur adoption by farmers in similar agroecological zones in Morocco, Tunisia, and other countries.

Finally, most previous public investments in agriculture in WANA have targeted irrigated areas. The results of this study should encourage policy-makers and donors to invest in marginal rainfed areas. On the basis of their experience the governments of Morocco and Tunisia are already thinking in these terms.

What next?

Secure land tenure is a key determinant in the adoption of NRM technologies in the drylands. This issue may need more attention in the future as efforts are made to scale up alley cropping technologies and adapt them to a broadening set of conditions.

As the Tunisian experience shows, markets have a strong influence on rates of return. Future efforts to increase adoption levels will therefore need to be targeted to areas with good access to markets.

The study showed that assessing the impact of NRM research, in the drylands as in wetter areas, requires methodologies that go beyond conventional economic and biophysical models. It is necessary to capture the holistic nature of the problems of these environments by integrating economic, environmental, and social aspects. The long-term environmental impacts of NRM technologies can be accurately assessed only when simulation models are used. Unfortunately, few suitable models of this kind are yet available. Future research should focus on their development and calibration for marginal drylands.

Notes

1 ICARDA. 2002. Mashreq/Maghreb project, Annual Report for 2001/02 season. International Center for Agricultural Research in the Dry Areas: Aleppo, Syria.

2 Further reading:
Alary V., Nefzaoui A., Elloumi M., and Mekki Ben Jemaa M. 2004. Application of a dynamic linear programming model on an *ex post* impact assessment analysis: the case of spineless cactus in alley cropping in central Tunisia, pp. 35–46 In: *EWDA-04 Proceedings of a European Workshop for Decision Problems in Agriculture and Natural Resources*, held at Silsoe, UK, 27–28 September 2004.
Shideed K., Laamari A., Boughlala M., Benouda H., Mahyou H., Mrabet R., El Mourid M., Aw-Hassan A., Hammudi M., Rahmi M., El Mzouri H., and Thomas R. 2005. Documenting the impact: How effective is *Atriplex* alley cropping? *ICARDA Caravan 22 (June 2005)*, 34–36.

Prepared by Green Ink Ltd (www.greenink.co.uk)

CGIAR
Science Council Secretariat
A Unit of the CGIAR System Office
c/o FAO
Viale delle Terme di Caracalla, 00153 Rome, Italy
www.sciencecouncil.cgiar.org
t: 39 06 57056696 f: 39 06 57053298
e: sc-secretariat@fao.org

October 2006