Adoption of green manure and cover crops

Roland Bunch

Worldwide, green manure and cover crops (gm/cc's) have proven to be a successful technology for maintaining soil fertility and controlling weeds. The numerous advantages of gm/cc's have led to their widespread adoption in many parts of the world. In other areas, however, farmers have been reluctant to adopt these crops. Moreover, farmers are also known to have abandoned traditional systems. The question is why the introduction of gm/cc's has been a success in one area, while similar programmes have failed in others? Under what conditions can we expect small-scale farmers to be interested in growing cover crops?

Farmers clearing a field with Mucuna in Veracruz, Mexico in preparation for planting maize. Photo: IDRC

After 20 years of experience with gm/cc systems around the world, I would like to discuss the main conditions for adopting green manure and cover crop systems. The following conclusions are based on experiences with 140 different systems, involving 41 species. Sixty percent of these systems have basically been developed by farmers themselves, which shows how appropriate these systems are for farmers and how interested farmers are in them. This article summarises some of the lessons learned from my experiences with programmes and organisations that have been successful in introducing sustainable gm/cc systems.

Opportunity costs

Green manures or cover crops should be grown on land that offers farmers few other opportunities such as income, food, fodder, etc. Generally, farmers are not interested in planting something that only fertilises the soil when the same land could be used for either subsistence or cash crops.

This may seem to impose many restrictions for growing gm/cc's, but in fact we are finding more and more places and times when they can be used:

- If the gm/cc does produce a valued food, it can be grown in any way that fits into the system like any other crop.
- The gm/cc can be grown intercropped with another food for example jackbean with maize or cassava, or perennial peanut with coffee. This is presently the most popular niche for introduced gm/cc systems.
- The gm/cc can be grown on wasteland or on fields under fallow. Suitable species for these areas are gm/cc's that can survive on very poor soils, such as jackbeans, tephrosia, or particularly hardy trees. Farmers in Vietnam, for example, seed *Tephrosia candida* into their first year fallow, thereby reducing the normal five-year fallow to just one or two years.
- The gm/cc can be grown during the dry season, planted after the normal crops like the ricebean/rice system in Vietnam, or intercropped with the normal crop and then allowed to grow through the dry season such as the sweet clover/maize system in Mexico. It can also be planted as a relay crop amongst rainy season crops at the end of the wet season to take advantage of the moisture still in the soil, such as the cowpea/maize and lablab/maize systems in Thailand.
- The gm/cc can be grown under fruit trees, forest trees or almost any perennial crops. In this case, particularly shade-tolerant species, like jackbeans or *Centrosema pubescens* are chosen.
- Other small, occasional niches can be found, such as during periods of frost (lupines, such as tarwi, often do well), in extremely acid soils (velvet bean or buckwheat), or during very short periods of time (*Sesbania rostrata*).

Jackbean (*Canavalia ensiformis*) is probably the second most widely used introduced green manure and cover crop. It is resistant to drought, poor soils, insects and diseases and is capable of surviving and growing well in the worst conditions. The jackbean can be used during the dry season and in very marginal environments where crops will not grow. It has an ability to fix large amounts of nutrients and is also capable of helping wastelands to regenerate.

Cash costs

Growing green manure and cover crops should involve minimal, or no cash costs. This implies that farmers should be able to produce their own seed year after year, and that these crops should be resilient to disease or insect problems. Preferably gm/cc's should save farmers money. They can reduce the amount of money farmers spend on chemical fertilisers. In addition, they can lead to a reduction in or even a total elimination of herbicides. Some species can also be substituted for certain chemicals: the velvet bean is a wide-spectrum nematicide, and sunnhemp (*Crotalaria ochroleuca*) can be used to control grain storage pests.

Labour demand

The gm/cc selected should not lead to an increase in the amount of work farmers have to do. In fact, when intercropped, gm/cc's can save on labour because they can shade out weeds. This reduction in labour required for controlling weeds can in many cases counterbalance the labour needed for planting and cutting the cover crop. Furthermore, farmers can often be partially motivated to plant gm/cc's by the prospect of never having to plough or hoe their fields again: the technology offers the possibility of moving to a zero till system.

Other benefits

The gm/cc's chosen should provide at least one major benefit other than improving the soil. Farmers seldom choose gm/cc's because of their effects on the soil fertility. Usually, farmers are motivated by the potential of gm/cc's to support food production (which usually has a high priority) or to control weeds. The most commonly used gm/cc's, such as pigeon peas, common beans, soybeans and scarlet runner beans are grown for human food. Velvet beans (*Mucuna* spp.), usually not eaten by humans, are also popular cover crops, probably because of their ability to smother aggressive weeds and effectively control nematodes and several plant diseases.

Experiences with projects introducing gm/cc's show that systems that produce benefits other than soil improvement tend to last longer and continue after the "project" has come to an end. This can partly be explained by the fact that soil improvement is a long-term process, which is not immediately noticeable to farmers. The long time that it takes for positive results to emerge is an obstacle to the more widespread adoption of gm/cc's. Therefore, it is often preferable to promote gm/cc's for reasons other than soil fertility. Thus, whenever possible, we should choose gm/cc species that can be eaten, fed to animals or provide some other benefit which farmers need. For example, farmers grow scarlet runner bean (*Phaseolus coccineus),* intercropped mostly with maize, for the edible bean, even though they also realise its importance for conserving soil fertility.

Finally when considering the introduction of gm/cc's, the demand for the products of green manures and cover crop should also be considered. The demand may not be very great if people do not like to eat beans or sprouts, when farmers only have few animals to feed, or when they have already sufficient fodder for the animals.

Existing farming systems

Green manure and cover crops must fit into the existing farming systems. At least for the first few years these crops will be seen as much less important than food or cash crops. They will have to be adjusted to fit into the existing farming system, not the other way around.

Furthermore it is important to understand when, and to what extent farmers would prefer slow maturing tree species and when farmers would prefer fast maturing, less woody and shorter statured plants in their fields. Planting trees as improved fallow is only an option if farmers already have fields under fallow: otherwise it will be too expensive. Whether farmers would prefer a gm/cc system above a tree based system will depend on the relatively demand of the products of both systems. If farmers have rights or gain rights to land by planting trees, they will probably prefer tree-based improved fallow technologies above gm/cc's. Furthermore, many tropical crops do better with a light shade (say 20 to 30%) than with either a heavy shade or no shade at all. Thus, "dispersed tree" systems can very often be ideal for crop growth. And, of course, a dispersed tree system provides a better environment for gm/cc's than total sunlight.

In Brazil, gm/cc's are widely used by farmers with landholdings up to 100,000 hectares. On the other hand, gm/cc's are useful for resource-poor farmers as well, provided that they have sufficient land to allow the incorporation of gm/cc's without affecting the regular cropping system. If farmers have sufficient land to practise shifting cultivation with long fallow periods, farmers may not be interested in gm/cc's.

At farms with little land, the use of the land is often so intensive that there is virtually no time or place when the opportunity cost is very low. In these cases, farmers may be better off using compost or buying soil amendments.

Specific characteristics

Green manure and cover crop species should fit the available niche(s). In general, good gm/cc species should have the following characteristics: easy establishment; vigorous growth under local conditions; ability to cover weeds quickly; and the ability to either fix plenty of nitrogen or concentrate plenty of phosphorus. They should be resistant to insects, diseases,

The role of gm/cc's in rehabilitating degraded land

Green manure and cover crops can contribute to the rehabilitation of degraded lands and the restoration of wastelands in various ways. The most important impacts and effects of gm/cc's are listed below.

Increased organic matter and nutrient cycling. The organic matter from gm/cc's has, in turn, a whole series of positive effects on the soil, including making soil nutrients more accessible to crops. For example, in acid soils phosphorus may be four to five times more available to plants when surrounded by organic matter.
Nitrogen fixation. Organic matter often adds significant quantities of nitrogen to the farming systems. Many, if not most, of the widely used legumes are capable of fixing more than 75 kg/ha of N, while a few species fix a good deal more: the velvet bean can fix 140 kg/ha/crop, the jackbean up to 240 kg/ha, and Sesbania rostrata is capable of fixing 400 kg/ha.
Weed control. Intercropped with food or cash crops, green manure/cover crops are important for controlling weeds and consequently they reduce farmers' labour requirements and costs. Additionally, gm/cc's are also known to be able to control very aggressive weeds. In West Africa, for example, velvet beans (Mucuna spp.) are largely grown to control Imperata grass.
Soil conservation. The soil cover provided by the green manure/ cover crop protects the soil from erosion.
Improved soil moisture. The soil cover plus the increased infiltration and water holding capacity brought about by the organic matter, often increases the crops' resistance to drought.
Zero tillage. After a few years of heavy applications of organic matter from gm/cc's farmers can move to zero tillage systems that retain very high levels of productivity.
Control plant diseases and nematodes. Gm/cc's can reduce, and in many cases totally eliminate, the use of pesticides.

Green manure and cover crops can play an important role in the restoration of wastelands. Their use can result in such a significant increase in soil fertility that it is possible to speak not just of soil conservation, but of soil restoration and soil recuperation.

Extremely low or irregular rainfall, extremes in soil pH, severe drainage problems, or combinations of these problems, which are all too common on the farms of resource-poor farmers, will reduce the growth of gm/cc's, thereby reducing or destroying their impact. Through the years, we have learned how to overcome an increasing number of such problems, often using gm/cc's species that are particularly resistant to specific problems. However, such solutions are often achieved at the cost of reduced biomass production, reduced nitrogen fixation, and reduced additional benefits.

Nodules on the roots of Mucuna pruriens formed by Rhizobium soil bacteria. Photo: IDRC

grazing animals, bush fires, droughts, or any other problem they may have to face within the desired system. They should also have multiple uses, and should produce viable seeds in sufficient quantities for future plantings. If they are to be used for intercropping, they should tolerate shade and fit in with the cycle of the main crop(s).

Some species that have been introduced may establish themselves so successfully that they become pests. Great care should be taken not to introduce potential pests. Known candidates are common kudzu (*Pueraria lobata*), tropical kudzu (*Pueraria phaseoloides*), and even perennial peanut (*Arachis pintoi*) and perennial soybean.

The more ecological deterioration that has taken place, especially as far as soil quality and rainfall regularity are concerned, the more limited will be the selection of gm/cc species that grow well. Nevertheless, in a year or two, when these gm/cc's have improved the soil somewhat, farmers can often graduate to less hardy varieties that produce more subsidiary benefits.


Jicama (Pachyrhizus erosus) is a food crop that can also be used as a cover crop. Photo: CIDICCO

Conclusions

We have learned, while trying to apply these rules in many different situations around the world, that finding acceptable, widely adopted systems for (or preferably, with) farmers requires a great deal of flexibility and creativity. No textbook is able to tell us exactly what technology could or should be used in any particular case. We have to be open, listen to and learn from the local farmers, and then work together with them to find out which species and which systems will best fit their particular situation.

Generally, the most successful way of doing this is to first observe the local farming systems, and look for an appropriate niche: traditional crops among which gm/cc's could be intercropped, times during the growing season when lands are left idle, or perennial crops around which gm/cc's can be grown. In the absence of these possibilities, one can try growing the gm/cc during the drier seasons or as improved fallow. After identifying the best niches, one should select for experiments those species that are known to function best in those niches that will provide the benefits most desired by the farmers with the least amount of labour.

In order to introduce green manure and cover crop systems successfully, we need a much better understanding of existing systems. We need to understand the geographical extent of present systems, the rates of adoption or abandonment, and the reasons why gm/cc's have been accepted or rejected. At the moment research into finding ways that the most common gm/cc's can be used to feed different animals is a high priority. Innovative associations of gm/cc's need to be investigated as well as the associations between these and common crops. We also need to know a good deal more about the theory of inter-cropping and the mechanisms by which gm/cc can lead to zero tillage. What are the minimum requirements to move to zero tillage, and how can these be easily achieved under different conditions? New gm/cc species need to be found which can respond to farmers' needs. Virtually all of this research can and should be done in the field through participatory processes. ■

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Table 1: Characteristics of some important GM/CC species

Common name	Scientific name	Resistance to shade	Resistance to poor soil	Resistance to drought	Controls weeds	Other uses
Velvetbean	Mucuna spp.	3	3	3	4	Medicine, animal feed, human consumption (when processed)
Jackbean	Canavalia ensiformis	4	4	4	3	Human consumption (tender pods)
Cowpea	Vigna unguiculata	3	3	Some vars. 4	3	Human consumption
Pigeon pea	Cajanus cajan	3	3	4	2	Animal feed, human consumption
Tephrosia	Tephrosia vogelii or T. candida	2	4	4	2	Insecticide

4 = extremely good 3 = good 2 = fair 1 = poor