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The Dark Green Farming Revolution in West Asia and North Africa

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Contents

Abstract

A new dark green farming revolution provides the potential for increased food production from the dryland regions of North Africa and West Asia. The opportunities are much greater than indicated by the conventional wisdom. More importantly, changes to the farming system can greatly increase farmers' profits. A prosperous farming community is the bedrock of national food security.

At present the scientific community is reluctant to admit that the first green revolution of the 1960s does not work in dryland zones. That green revolution was based on large amounts of nitrogen fertiliser, new crop varieties and ample supplies of water either as reliable rainfall or irrigation. The scientific explanation for the failure of this package in dryland zone is well researched and documented and we need to move on to alternative farming systems that are adapted to the unreliable rainfall. Even if the problems of nitrogen fertiliser could be fixed through more complex technology we need to ask whether farmers can afford the high cost of nitrogen and whether the world can afford the pollution. Nitrogen fertiliser is liquid or solid energy and when it is applied to farm land the reactions in the soil release nitrous oxides which are 310 times more polluting as green house gases than carbon dioxide. Unreliable moisture levels in dryland soils increase the loss of nitrous oxides.

During the 1970s and 1980s there was a wave of interest in using legume pasture in rotation with cereals as a means of increasing livestock production and replacing nitrogen fertilisers. This wave started in Libya and spread as far as Iraq in West Asia and Morocco in North Africa. We describe the use of legume pastures, based mainly on medic (a self-regenerating annual legume) in our book “Sustainable Dryland Farming” (Lynne and Brian Chatterton, Cambridge University Press). That wave of innovation has dissipated due to wars, sanctions and chronic under-investment in extension and farm machinery. Legume pastures have dropped off the agenda of international institutions who have returned to the conventional ideas of the past with their proven track record of failure. While institutions may have failed to understand and develop legume pasture systems, farmers have not forgotten them and innovations over the last several decades have transformed the legume pasture rotations of the 1970s and 1980s into systems that are better adapted to the needs of farmers in North Africa and West Asia. This paper will report on these exciting developments (usually described as the Zaghouan 4 rotation) which have passed under the institutional radar and which provide great potential for the improvement of dryland farming in the WANA region.

1. The first green revolution

For too long we dryland farmers have been living under the shadow of the first green revolution. The first green revolution swept around the world from the 1960s onwards, transformed the food security of most Asian countries and produced huge surpluses of grains in northern temperate regions.

The first green revolution was based on large amounts of nitrogen fertiliser, crop varieties that responded to nitrogen and a reliable supply of water either in the form of irrigation or rainfall. It was not "green" at all in the modern sense of that word as nitrogen fertiliser is liquid or solid carbon-based energy and the nitrous oxides released from the soil by bacteria acting on the fertiliser are 310 times more polluting than carbon dioxide as a green house gas. The release of nitrous oxide from the soil is greater under the variable moisture conditions found in dryland zones.

Table 1 Shows the use of nitrogen fertilisers and their carbon dioxide footprint from 1960 to 2006

Nitrogen fertiliser consumption 1960 to 2006		
YEAR	DEVELOPED WORLD Millions tonnes	DEVELOPING WORLD Millions tonnes
1960-61	8.55	2.28
1980-81	35.79	24.9
2005-06	27.17	63.69
Carbon dioxides footprint 2005-06	182 million tonnes	427 million tonnes

Nitrogen fertilisers consist of different compounds with different amounts of the element nitrogen. The various types have been converted to tonnes of the element N.
Source: International Fertiliser Industry Association

The first green revolution has failed in dryland farming regions because of the unreliable rainfall. The cereal-nitrogen package does not work without adequate moisture. The science is well understood. To summarise, the nitrogen fertiliser applied to the crop encourages each plant to produce more shoots. Each shoot produces a seed head and the grain yield is usually increased. In dryland areas the unreliable rainfall in spring means that more shoots mean more competition for limited water. Mild moisture stress means more grains each of which weighs less. The yield is no greater than a traditionally grown crop. With acute moisture stress the heavily fertilised crop yields less as the loss of weight in each grain is greater than the increase in the number of grains.

The situation on farms is worse than the trial plots. Research centres in West Asia and North Africa tend to be in the areas with better rainfall and better moisture holding soils where spring moisture stress is less frequent. Some centres such as ICARDA use irrigation to avoid abnormally dry spring rainfall. Speaking as a dryland farmer myself, I know that abnormal weather is frequent in dryland areas.

Some researchers believe that technology can solve the problem. Soil analysis, leaf analysis and small, frequent applications of nitrogen will reduced the chance that the yield of grain will decline. Even if such a complex system could be made to work the question remains whether the farmers can pay the cost and whether the world can stand the pollution.

In spite of the failure of the first green revolution in the dryland zones, it constrains the research institutions. They are incapable of thinking of alternatives and believe in spite of all the evidence that they can make the package work one day.

One way to avoid a dry spring is to sow early. This is easy on a research centre with abundant resources of machinery, herbicides and labour. On real farms not all the crops can be sown early and are therefore more vulnerable to dry spring weather. Lower yields on farms tend to be dismissed by researchers as being due to the farmers' lack of understanding. They are considered as being not as smart as the scientists but the reality is the farmers do not have the resources. More resources will not necessarily solve the lack of response to nitrogen either. Perhaps the response will be better but the farmer will still fail to make a profit because of the cost of the extra resources.

The results from the trial plots take no account of risk. The responses to nitrogen are aggregated to produce a mean. Even if this means shows profitable increase in yield over a period of years, a small farmer may not have the resources to take the risk. If two or more years of depressed yields occur at the beginning of the period, he will have lost too much of his working capital to continue with any fertiliser applications at all.

The final irony is that most countries in North Africa and West Asia subsidise nitrogen fertiliser to make it more competitive compared to locally produced bio-fertiliser. Locally produced nitrogen from pasture legumes is cheaper and more effective even without any subsidy support.

2. The dark green farming revolution

The dark green farming revolution is based on legumes. They provide nitrogen to the following cereal crop but release it slowly. I have not been able find a single trial where legume nitrogen, unlike chemical nitrogen, reduced crop yields.

Of course legumes have been used in agriculture for thousands of years but the Dark Green Farming Revolution uses a different class of plants to the traditional legumes such as lentils, chick peas or even lucerne. The new rotations within the Dark Green Farming Revolution use self regenerating, annual, pasture legumes. These were recognised as being useful for farming during the 1880s by Amos Howard from Mount Barker in South Australia and were used initially just for pastures on non-arable land in dryland zones. During the 1930s and 1940s this new class of legumes were incorporated into rotations with cereals by farmers in Australia.

Until Howard's discovery, farmers had used annual plants such as wheat, barley or lentils which were sown every year or perennial plants such as olives, vines or lucerne which survived for many years or decades. The self-regenerating group are annuals, like medic, that drop their seeds on the ground. The pasture regenerates in the following wet season without the farmer cultivating the land or sowing the seed. This mechanism is a highly successful adaption to dryland conditions. Most weeds follow this path. Medics and other annual legumes can be regarded as beneficial weeds if that is not a contradiction in terms.

Researchers are still struggling to come to grips with these legumes because they are too narrowly focused on increased yields in their trial plots. Yield increases are not the point for self-regenerating legumes. They are a farmers' pasture. They cost less. They require less work, use less machinery and less seed. They allow farmers to concentrate their efforts on early sowing of the cereals in the rotation. Time, cost, and machinery use are all outside the ambit of the agricultural research centre.

The Dark Green Farming Revolution has genuine "green" credentials. The use of nitrogen fertiliser is eliminated with its high level of green house gas pollution. The other environmental crisis in North Africa and West Asia is soil erosion caused by destructive crop rotations. Legume pastures restore organic matter in the soil. The absorption of rainfall increases and runoff deceases. While the Zahgouan 4 rotation includes a cultivated fallow, it is one year in four rather than one in two. The intermediate period of legume pasture restores the organic matter in the soil to a high level.

Table 2. Shows the mean yield of wheat from various dryland farming rotations. The trials were carried out at the Waite Institute of the University of Adelaide in South Australia. The climate at the centre is almost identical to that of Tunis. The soil is slightly more acidic so subterranean clover was used rather than the more common medic cultivars but this is of no importance. While farmers developed various legume pasture and cereal rotations in the 1930s and 1940s they were not recognised by the research establishment until the 1950s. (Source Waite Institute Annual report 1985)

Dryland farming rotations	Means yield of wheat Kg/ha	
	Period 1926 to 1951	Period 1952 to 1983
Continuous wheat	874	692
Wheat-cultivated fallow	2300	1403
Wheat - grain legume (peas)	1668	1420
Wheat – self-regenerating legume pasture - legume pasture no fallow (3 years)	Not included	2033
Wheat – self-regenerating legume pasture - legume pasture - legume pasture/cultivated fallow (4 years) The Zaghouan 4 year rotation	Not included	2402

The above table confirms what we all know about the top two rotations most commonly used in North Africa and West Asia. They can be productive for a surprisingly long time but they are exploitative and will decline in the longer term. Even the wheat - grain legume rotation performed badly over the long term. While grain legumes fix nitrogen from the air most of it is removed with the crop and there is little benefit for the following cereal crop.

The second half of trial used two rotations based on self-regenerating legume pasture. One had cultivated fallow and one did not.

Table 3 Shows the net production of wheat from four of the above rotations over a four year period. Grain legumes have been excluded because the Waite Institute Annual Report did not give the yield of peas in the rotation. I have assumed a seeding rate of 100 kg of wheat per ha. For example the continuous wheat produced 2768 kg over four years but 400 kg were used to sow for crop. On the other hand the Zaghouan 4 produced 2402 and required only 100 kg of seed leaving 2302 as the net output.

Total net production of wheat over four years from various dryland farming rotations.	Production in kg/ha over the four years.
Continuous wheat	2368
Wheat-cultivated fallow	2606
Wheat – self regenerating legume pasture - legume pasture no fallow (3 years)	2577
Wheat – self regeneration legume pasture - legume pasture - legume pasture/cultivated fallow (4 years) The Zaghouan 4 rotation	2302

While I have deducted the amount of cereal seed I have not allowed for any other costs. Cereal seed after it has been cleaned and treated with fungicides usually costs double the price that the farmer gets for the grain he sells. In money terms, the continuous wheat rotation would produce a net amount of 1968 kg over four years while the Zaghouan 4 rotation would produce 2202 kg. The cost of seeding, fertiliser, and harvesting all relate to the area so continuous wheat rotation with four times the area sown would cost four time as much as the Zaghouan 4 rotation. If these are taken into account the farmer is much better off with the legume pasture rotations than either the continuous wheat or wheat-fallow rotations.

3. Food security

Food security tends to be focused on cereals. There are many other essential foods and it is a great mistake to compare these rotations on cereal production alone.

Table 4 Shows the production from the four rotations when livestock are included. I have excluded the stubble grazing because the output of stubble is roughly equal to the output of grain. There is not a great different in stubble production from any of the rotations.

Total production of wheat and livestock over four years from various dryland farming rotations.	Net production of wheat in kg/ha over the four years.	Livestock excluding the grazing from the cereal stubble over a four year period.
Continuous wheat	2368	NIL
Wheat-cultivated fallow	2606	1 sheep (0.5 per year of fallow) = 365 kg of barley
Wheat – self regenerating legume pasture - legume pasture no fallow (3 years)	2577	11 sheep (4 per ha. on pasture) = 4015 kg of barley
Wheat – self regenerating legume pasture - legume pasture - legume pasture/ cultivated fallow (4 years) The Zaghouan 4 rotation	2302	10 sheep (4 sheep per ha on pasture) = 3650 kg of barley

When the livestock figures are included, the legume pasture rotations leap ahead in terms of profitability for the farmer. In North Africa and West Asia sheep prices are extremely high by world standards and returns from sheep on legume pastures are higher than for a cereal crop. For small and medium sized farms the relative returns are even more favourable for livestock. Cereal production has many economies of scale which are not available to the smaller farmers.

Even the policy makers who are narrowly focused on cereals should not ignore the advantages of the legume pasture rotations. While cereal output is not significantly different in the above tables, the savings in imported grain for livestock are considerable. National grain balances are considerably improved. I have calculated some approximate barley equivalents for the pasture and they show that the legume rotations are more profitable for the farmer and much more productive in terms of grain imports saved.

The Dark Green Farming Revolution provides another intangible addition to grain security. It provides a bank of fertile soil that can be cashed into grain production. With the current high livestock prices farmers in North Africa and West Asia will prefer longer rotations with more legume pasture. These can be shortened at any time in response to price signals. If livestock prices fall and cereal prices increase, farmers can easily change the balance between legumes and cereals.

4. Medic comes home

The legume pasture rotations were developed in Australia by farmers not scientists. They used a variety of self-regenerating, pasture legumes of which the most important was medic. Medic is the short hand name for annual species of medicago. Medic is not native to Australia but was imported from North Africa and West Asia where it has almost disappeared under the combined attack of cultivated fallow and deep ploughing.

During the 1970s and 1980s the medic-cereal rotation came back to its homeland. Libya was the pioneer but Tunisia and Algeria followed shortly afterwards. Later Jordan, Iraq, Syria and Morocco experimented with medic rotations. It was a resounding technical success. That is it produced the output increases one would expect from the above trials. However it failed to supplant the existing rotations on a wide scale and by the 1990s the wave of interest faded and the amount of medic pasture declined.

Wars and sanctions played their part by cutting off supplies of medic seed and machinery from Australia but the major reason was chronic under-investment in training, extension and machinery.

The classic medic rotation as practiced in Australian and imported into North Africa and West Asia in the 1970s and 1980s applied "innovation over-load" onto the local farmers. They had to acquire new skills in sowing pastures with smaller seeds than they had ever sown before. They had to understand new concepts of grazing management and most difficult of all they had to abandon the fallow and to use shallow cultivation to sow their cereal crops. Australian farmers had taken more than 100 years to put these pieces of the medic rotation together but in North Africa and West Asia, only Libya realised the gravity of the problem and employed expert farmers as trainers and extension agents. They also realised that shallow cultivation needed machinery designed for that task and adapting existing machinery was not a feasible option. Libya had the greatest and most wide spread success with tens of thousands of hectares of medic pasture in both the cereal zone and rangeland. Elsewhere farmers were left to struggle without advice and the proper machinery. Extension material on medic was only produced in the late 1980s when interest in medic was already fading. Training colleges and universities failed completely to include medic in their courses.

Table 5 The figures in this table give some indication of the transformation of cereal yields and sheep numbers in South Australia due to the use of legume pastures. Algeria is still waiting for a Dark Green Farming Revolution. I have used the 1970s figures because the major impact of the Dark Green Farming Revolution was in the 1950-70 period. Yields have increased considerably since 1970s in South Australia but can be attributed to other technological advances. The gap in cereal yields and livestock production with Algeria has increased.

	South Australia		Algeria
	1930s before the Dark Green Farming Revolution	1970s after the Dark Green Revolution	1970s and still waiting.
Wheat production – '000 tonnes	888	1327	1270
Wheat yield – Kg/ha	735	1139	624
Sheep numbers '000	8500	18961	8357

These figures probably under-estimate the impact of legume pastures as South Australia exports barley and other sheep feed while Algeria imports feed for its sheep.

I am sure that the introduction of medic pastures into Algeria would feed another 10 million sheep without any costly imported grain. This would boost farmers' incomes by a very substantial amount as Algeria has one on the highest prices in the world for sheep meat. Cereal production would also increase by a useful 65%.

5. Zaghouan 4 rotation

The Dark Green Farming Revolution provides the opportunity to greatly increased livestock and cereal production throughout the dryland farming areas of North Africa and West Asia. It would be theoretically possible to revive the classic medic rotation as used in the 1970s and 1980s which failed to reach take off due to under-investment, wars and sanctions. Since the 1980s the lack of investment in agriculture has intensified. Writing a report or passing some resolutions is not going to change that downward trend. Governments are seeking to reduce expenditure and many economists are advising them to cut agriculture. They believe that agribusiness can introduce innovations and there is no role for public investment.

Agribusiness will never support the Dark Green Farming Revolution. Medic is a low cost system. Low cost means low sales of inputs to farmers. It means cheap phosphate fertiliser instead of expensive nitrogen and phosphate. It means cheaper tractors and machinery. This is not a good system for agribusiness profits.

Given these severe constraints, I developed the Zaghouan 4 rotation while working for IFAD in Zaghouan, Tunisia. I identified three major problems with the classic medic rotation that created the innovation over-load when it was transferred to North Africa and West Asia in the 1970s and 1980s.

The establishment of the medic pasture in the first year was difficult as the farmers did not have the correct machinery nor the experience to sow small seeds. I took some work done by ICARDA on sowing medic pods instead of seed. The idea had come from some Syrian farmers in the village of Tah but had been developed by ICARDA. Pods can be collected by the farmers themselves and broadcast over the germinating cereal crop.

Grazing management in Australia is completely different from North Africa and West Asia as sheep numbers are adjusted to alter the grazing pressure in response to pasture growth. That is not feasible in the region particularly on small farms so I used a new system I developed when I was preparing some training kits for FAO. Instead of adjusting numbers one adjusts grazing time. As the sheep are permanently controlled by shepherds this is not difficult.

The third and most substantial hurdle for the classic medic rotation was shallow cultivation and the elimination of the fallow. The cultivated fallow is most destructive and a major cause of the soil erosion crisis in the region but it is a most effective means of weed control. In the classic medic rotation, fallow is eliminated altogether. Farmers must control the weeds in the short autumn period. They must do this with shallow cultivation as deep ploughing will bury medic pods so deep they will not regenerate in future years. The use of shallow cultivation proved to be so difficult because most universities and colleges provide very little training to agronomists in the use of farm machinery. The agronomists in turn could provide no assistance to farmers struggling with an unfamiliar technique. The research establishment was even less informed and carried out many experiments which only proved they also knew nothing about tillage. The trials were poorly designed and instead of helping advisers in the field they only confused them.

One can see this is quite a formidable package of innovation and farmers found it difficult to cope especially as they had so little advice and no appropriate machinery. Of course Libya is always the glorious exception. The Libyans provided machinery and advisers to show how it worked. The Zaghouan 4 rotation leaves the fallow and deep ploughing in place. This means the pasture does not regenerate but has to be sown again. With the pod method, sowing is cheap and easy so this should not cause problems for the farmer. It would however be too much work to reseed the medic every other year so I have expanded the rotation to one cultivated fallow and one cereal crop in a four year cycle. Given the high returns from sheep, I am confident that farmers will increase their returns and reduce their costs using this rotation.

I do not pretend to like the cultivated fallow in the Zaghouan rotation. It is costly in terms of lost production and the destruction of the soil structure. Nor do I like deep ploughing. It is also costly and unnecessary. Leaving both in place will I hope be a transition to more productive rotations without fallow. The Zaghouan 4 rotations gives farmers the choice. They can balance the cost of fallow and reseeding the pasture against the cost of purchasing new machinery. Only when they are confident of the new rotation will they make the investment.

6. Implementation

With the low priority given to agriculture it is not going to be easy to introduce a completely new farming system. Previous attempts to introduce medic rotations failed due to lack of investment, so how can they be revived when investment levels are even lower?

Firstly we do not need to worry about research. ICARDA sensibly abandoned its medic research more than a decade ago because the barriers to the adoption of medic pastures are farming problems not technical ones.

Next we can take the machinery replacement much more slowly. As machines wear out they can be replaced with those designed for shallow cultivation.

We need to concentrate on training and extension. Extension material is cheap, very cheap indeed. On the IFAD projects I worked on over many years the budgets were in millions but the total extension component was only a few hundred thousand and this portion was usually underspent. If we want to introduce the Zaghouan 4 rotation we should produce some extension material before the program starts, not twenty years afterwards as we did with the classic medic rotation.

Extension material is a good start but farmers need more than a booklet or film to understand a new rotation. Libya had a huge success using farmer to farmer training in the 1970s and 1980s and IFAD has recently taken up the same idea in Madagascar and Rwanda to introduce new methods of rice growing.

The use of farmers as extension agents will be resisted by the agricultural bureaucracy but government changes in Libya and Tunisia and perhaps other countries in the future will hopefully allow the formation of farmer groups that can develop a grass roots exchange of farming knowledge.

7. Wider application

Medic, sub clover and other annual self-regenerating pasture legumes used in North Africa, West Asia and Australia are adapted to a Mediterranean climate. They grow during the autumn, winter and spring. They survive the hot dry summer in the form of seed pods. They are drought evaders not drought resisters. They are not suited to dryland farming regions with a summer rainfall pattern but the concept of drought evasion has wide application. There are plenty of other self-regenerating, pasture legumes for these regions of the dry tropics. They could be used to produce cheap, nutritious, legume pastures for livestock and nitrogen for cereals.

8. Conclusions

The greatest advantage of the Dark Green Farming Revolution is that it makes money for farmers. Most of the increased profit will come from livestock. Not only will livestock production increase but costs will fall as grain feeding is eliminated. Cereal production will increase but from the farmers' point of view it will be much more profitable due to a considerable fall in costs.

Food security for countries in North Africa and West Asia will improve due to increased production of cereals and meat. Grain imports - particularly for livestock feedstuffs - will fall. The bank of fertile soil is an additional benefit that can be used in times of high cereal prices.

The Dark Green Farming Revolution reduces atmospheric pollution and soil erosion.

The technical success of medic and other self-regenerating pasture legumes was effectively demonstrated in North Africa and West Asia in the 1970s and 1980s but it failed to reach take off due to wars, sanctions and under-investment. The Zaghouan 4 rotation offers a new opportunity for farmers in the region. While it may not be the most productive or profitable rotation it is better adapted to the skills and equipment currently available.

Implementation of the the Zaghouan 4 rotation will not succeed if we rely on the agricultural establishment of research centres and ministries of agriculture. We have to accept it is a farming system developed by farmers and it needs farmers to be given a major role in its implementation.

Further reading

For more information on the classic medic rotation and its transfer to North Africa and West Asia during the 1970s and 1980s:

Sustainable dryland farming - Combining farmer innovation and medic pasture in a Mediterranean climate. 1996. Lynne and Brian Chatterton. Cambridge University Press.

For more information on the technical aspects of medic and the Zaghouan rotations:

Dryland Farming Organisation in West Asia and North Africa. Web site www.drylandfarming.org