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Quelles stratégies pour une agriculture des territoires et une croissance durable ?

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La restauration des terres dégradées au Portugal

Rehabilitation of degraded lands in Portugal

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1. Introduction

Nowadays, the need to feed a fast growing human population is challenging farmers and graziers to increase food production, but the need to prevent further negative effects on our Planet strongly recommend the adoption of methods and practices suitable to improve crop and animal yields without further deterioration of the environment. Indeed, most of the developments carried out in the last decades have been based on a prodigal consumption of fossil energy, in the form of heavy mechanization, absence of crop rotation, elimination of trees in traditional agro-forestry systems, and abuse of high energy consuming inputs, such as fertilizers, pesticides, herbicides, concentrate feed in ruminant animal production, etc., which in many situations led to loss of biodiversity, degradation of soil fertility, increased soil erosion, as well as to other environmental problems, such as atmosphere and water pollutions, desertification, etc., all with consequences on the balance of ecosystems and on climate change, and often also with a negative impact on the quality of the food produced. Although, in a long term, most of those systems are not economically and/or environmentally sustainable, requiring a deep change of paradigm, certain opinions are still considering that any increase in the production of human food will require higher fossil energy inputs, therefore continuing to aggravate environmental problems.

The theme of my intervention in this Seminar - "Rehabilitation of degraded lands in Portugal"- just presents an example of how we can sustainably restore the productivity of agricultural areas, which have been ruined by wrong agricultural practices, through the use of legume rich permanent pastures, able to significantly increase animal production at low cost, and simultaneously improve soil and water conditions, as well as mitigate the effects of climate change by reducing greenhouse gases in the atmosphere through the sequestration of atmospheric carbon dioxide in the soil.

2. Brief characterization of Portugal and causes of land degradation

Although situated in the front of the Atlantic Ocean, Portugal benefits from a Mediterranean climate, characterized by rainy mild winters and dry hot summers, where the mean annual rainfall may vary, according to regions, from less than 400 to more than 1000 mm, 85 % of which distributed from September-November to April-June, originating different ecological zones where herbage growing periods may range from less than 6 to more than 9 months, but in which animals can graze all the year round, although with some periods requiring feed supplementation.

Due to edaphic and topographic characteristics, from the total Portuguese agricultural and forestry land (6.7 million ha), 34.7% is occupied by forest, 27.3% by permanent pastures, 16.9% by agro-silvo-pastoral systems (Montado/Dehesa), 8.4% by permanent crops (olive groves, vineyards, fruit orchards), 7.5 % by annual or temporary forage crops and meadows, and only 5.2% by annual cash crops.

However, a considerable part of the area today under permanent pastures derives from areas which have been for long intensively cropped with heavily subsidized cereals (mostly wheat) as part of a past policy of food security which dominated until the country joined the EU in 1986, or even after, due to errors of the Common Agricultural Policy. Such policies resulted in very low national average wheat yields (800-1200 kg/ha), although these crops use to provide stubbles and straw as main sources of supplementary feed for grazing animals, thus creating in farmers the idea that ruminant animal production was not viable without cultivating cereals. Although the system has been abandoned due to lack of profitability, it has caused severe problems of land degradation induced by frequent tillage, such as soil erosion, combustion of soil organic matter, reduction of soil life and plant biodiversity, elimination of trees from agro-forestry systems, etc. As a consequence, most of the natural permanent pastures, occupying today large areas of these worn out soils (shallow, often stony and slopping, with very low fertility, particularly low in organic matter and phosphorous), are quite poor and carrying between 0.1 and 0.5 equivalent cattle units (C.U.) per ha and year, therefore providing very low economic returns which, in some cases, led to land abandonment, generally followed by shrub encroachment and sequent destructive fires.

In an attempt to feed better or more animals, many farmers rely on the application of high levels of nitrogen fertilizer to some natural pastures and meadows, on growing oats or annual ryegrass for forage production and conservation, as well as on the use of considerable amounts of concentrate feed. However, all those methods fail to provide satisfactory economic returns and just contribute to aggravate problems of soil and environment degradation.

3. How to recover degraded lands?

To reverse the situation, the author has conceived a system based on the fact of the Mediterranean Region being the Centre of Origin of a great diversity of herbage legumes, and on the capacity of these plants to fix high amounts of symbiotic nitrogen (N), in order to improve the yields and quality of the pasture at low cost, and simultaneously rebuilt soil fertility, stop erosion and have a positive effect on the farmer`s economy and the environment.

The so called “Sown Biodiverse Legume Rich Permanent Pastures and Forage Crops (SBLRPP&FC)”consist on a system in which at least 65-80% of the land used for ruminant animal production is occupied by sown permanent pastures to be grazed during all the year, and 20-35% is sown with annual forage crops to be grazed during autumn/early winter and/or cut in the spring to produce conserved forage for supplementing the grazing animals during periods of scarce quantity (early autumn/winter) or quality (late summer) of the rain-fed pastures. Ideally, permanent pastures should occupy all marginal lands, with annual forage crops being grown on the arable land available, if possible using minimum tillage techniques and being integrated in a rotation with other suitable crops (ley farming system).

Both permanent pastures and annual forage crops are sown with different mixtures of various species and cultivars, each one conceived to be well adapted to a particular soil and climate condition, and in which legumes occupy an important position, being complemented by grasses and eventually also by other herbs. The mixtures used for permanent pastures are formed by 12-20 different species and cultivars of annual self-reseeding plants (with hard seeds) and drought resistant perennials (with summer dormancy or deep root systems), and those used for forage crops are formed by 6-10 annual species/cultivars, including fast establishing plants well adapted to early grazing and with a good spring growth for cutting. To compose different mixtures, there are today more than 50 species varying in their characteristics of adaptation to different soil (pH, texture, depth, drainage, salinity, etc.) and climate conditions, and more than 200 cultivars with different lengths of vegetative and reproductive cycles, adjusted to variable rainfall patterns, or with different degrees of drought tolerance, frost resistance, etc.

In order to enhance nitrogen (N) symbiotic fixation and make the system independent of any N synthetic fertilizers, previously to mixing and sowing, the seeds of each legume species are inoculated with specific effective strains of *Rhizobia*. However, since legumes demand high amounts of phosphorous (P) to grow well, and most of the soils have very low contents of available P, we need to pay attention to this nutrient and provide it in adequate amounts, both at establishment and by topdressing in the following years. Fortunately, in grazed pastures about 70-80% of P contained in the ingested herbage is returned to the soil through the deposition of faeces and decay of plant residues, therefore it is required just to replace the exported amount through phosphate topdressing. The same happens with potash (K), whose application is also required in some soils, such as deep sands or derived from coarse granite. Sulphur, as well as calcium (Ca) and magnesium (Mg) are other important nutrients required, particularly these last ones in acid soils ($pH<5.4$) where the application of finely ground Ca+Mg carbonate may be needed before pasture establishment, in order to raise pH and improve the availability of nutrients. Eventually, in some less common situations, one or two micronutrients, such as molybdenum, boron, zinc, copper, etc., may also be required to enhance plant growth and/or persistence. However, the average cost of mineral fertilization required for the maintenance of this type of pastures and forage crops is in general quite low, particularly if compared with crops requiring abundant quantities of N fertilizers.

In order to favour a quick plant establishment, and a prompt formation of effective nodules of *Rhizobium* in the legume root system, these pastures and forage crops should be sown by the end of summer/beginning of the autumn, preferably on the occasion of the first effective rains of the season, and always before the soil temperature descends below 12º C.

Once a well-established permanent pasture is progressing in time, its composition and productivity may vary: i) inside a paddock, where it may form different niches according to variations in the soil (e.g. deep vs. shallow, well drained vs. waterlogged sites) or to different grazing pressures in parts of the paddock (e.g. heavy vs. light grazing); ii) between seasons or years according to the inter or intra-annual variability of rainfall (e.g. dry vs. wet periods or years). However, an adequate mixture containing a diversity of inter-compatible species/cultivars adapted to the average local soil and climate conditions, should assure a good persistency of the pasture, provided the grazing and fertilizer management is correct. Only when a mixture fails initial establishment due to an exceptionally severe dry period after sowing, a wrong choice of the mixture`s composition or to inadequate practices of sowing (e.g. inadequate method of seed bed preparation and seeding, too deep or too late sowings, lack of passing a roller to compact the seed into the soil, etc.), or fails persistence due to lack of adequate soil fertilization, or to grazing mismanagement, it is necessary to sow again.

It is important to keep in mind that the persistence of these permanent pastures, particularly those where self-reseeding annuals are dominant, depends on the formation and maintenance of an abundant seed bank, which implies avoiding heavy grazing during the flowering/seed maturing period, with total exclusion of grazing during that period in the first establishing year. Another important remark to assist pasture regeneration and persistence consists in removing through grazing most of the summer dry pasture before the first effective autumn rains arrive, as a dense cover of dry pasture prevents achieving good seed germination and a successful growth of the seedlings.

However, if we keep those simple rules in mind it is quite easy to maintain a pasture for a very long time. This is well demonstrated by many sown biodiverse legume rich permanent pastures, established in Portugal more than 40 years ago, which, in spite of having crossed various severe dry years, are still persisting and productive, compared with some others that due to lack of topdressing fertilizer (mainly phosphorous) or to wrong practices of grazing management, have failed.

When compared with natural pastures, these SBLRPP, apart from fixing higher amounts of symbiotic N (easily up to 80-160 kg N/ha/year, depending on the DM yield and content of legumes), have a much denser and deeper root system to uptake minerals and a more efficient leaf canopy to fix photosynthetic carbon, all resulting in: i) more N and organic matter in the soil, that means higher soil fertility, better soil structure and increased life in the soil ii) improved herbage yields and quality, that means increased animal production; iii) better soil cover, leading to higher rate of water infiltration and less runoff, i.e. less erosion, less floods, and increased water storage capacity of the soil; iv) benefits to the environment, through the sequestration of atmospheric carbon in the soil, and the replacement of synthetic fertilizer N by symbiotic N, fact that represents avoiding emissions of 8 kg of CO_2 per kg of N fixed.

4. **Some results**

A few examples obtained from various research/development projects carried out in Portugal show clearly some of the advantages above indicated.

One of these projects (Agro 87) entitled "Sown Biodiverse Legume Rich Pastures - a sustainable alternative to recover marginal lands" carried out in six rain-fed experimental farm units of 15 ha each, distributed throughout the country in areas of variable mean annual rainfall (from less than 500 to more than 900 mm), compared natural permanent pastures (NPP) in different stages of degradation, with sown biodiverse legume rich permanent pastures (SBLRPP). The pastures were grazed intermittently by sheep or cattle during 3 years and the dry matter yields and pasture composition obtained from samples collected inside mobile grazing exclosures, which also provided material for determining digestibility and crude protein content of the pasture. Comparing the contrasting results obtained from the initially more degraded land - an acid sandy soil (ASS) covered by poor herbaceous vegetation and shrubs, with the less degraded land - a neutral clay soil (NCS) covered by a good herbaceous natural pasture, we found that yields and quality of NPP have ranged from 993 kg DM/ha/year with 3% legumes, 31% digestibility and 10.6% CP, in ASS, to 4999 kg DM/ha/year with 32% legumes, 64% digestibility and 15,6% CP in NCS, while in the SBLRPP the range went from 2994 kg DM/ha/year with 42% legumes, 61% digestibility and 15.4% CP in ASS, to 8694 kg DM/ha/year with 50% legumes, 68% digestibility and 16.1% CP in the NCS. Therefore, by replacing NPP by SBLRPP we have multiplied by 5.9 fold the digestible DM (DDM) yields, and by 4.4 the CP yield in the ASS, , while in the NCS, we have multiplied by 1.85 the DDM yields and by 1.79 the CP yields, being evident the role of legumes in the yields and quality of the pastures.

Another study of this project, comparing the carrying capacity of both NPP and SBLRPP during 3 years in the 6 experimental farm units, demonstrated that it increased from an average 0,42 equiv. cattle units (CU)/ha/year in NPP to 1.03CU/ha/year in SBLRPP, corresponding to a 2.45 times increase, , thus showing that this type of improved low cost pastures may easily more than double the carrying capacity of natural pastures.

As already mentioned, SBLRPP are very efficient in increasing soil fertility, through symbiotic N fixation, the incorporation of dead roots, other pasture residues not consumed, and animal faeces. As pasture yields, legume content and associated symbiotic N fixation of SBLRPP are considerably higher than in NPP, and so are the corresponding carrying capacities, it is expected that soil organic matter (SOM) also suffers a considerable increase. This has been demonstrated in various experiments carried out in Portugal at farm level. In one of them (Project Agro 74), a trial carried out to follow the evolution of SOM in the top 0-10 cm layer of a shallow schist soil, in a zone receiving about 400 mm of annual rainfall, has shown that in 4 years, the SOM increased in NPP from an initial value of 0,85% to 1,45% while in SBLRPP it increased from 0,80% to 2,08%, corresponding to an average carbon sequestration of 5,95 and 12,80 t CO_2 equivalent/ha/year respectively.

Another study conducted on a 26 years old SBLRPP established on a "Montado-Dehesa" ecosystem, has shown that the sequestration of atmospheric CO_2 in the top 0-10 cm layer, decreased from 12.5 to 8.0 kg/m^2 when moving from the area closed to the trunks of the trees to open areas, out of the trees. In the10-20 cm soil layer, the sequestered CO_2 decreased from 7.2 to 4.7kg/m^2, respectively under and out of the oak trees. These figures show the valuable contribution of the trees to increase carbon sequestration, which is due to the fall of leaves, twigs and fruits on the ground, but also to the effect of shading in reducing soil carbon liberation to the atmosphere. It is also interesting to note that the amount of carbon sequestered in the 10-20 cm layer is approximately 60% of the values found in the 0-10 cm layer.

5. Achievements

Sown biodiverse legume rich permanent pastures and forage crops have been proved in Portugal since the middle sixties/early seventies, and from there they have passed to Spain, then to Southern Italy and are now initiating the first steps in Southern France. In total they occupy already more than half a million ha, being now on a crest of a wave for their recognised value as providers of high quality low cost feed to increase animal production of superior quality, capacity to recover degraded lands and to adapt and mitigate the effects of climate change. In Portugal, as well as in Spain, this type of permanent pastures are having an exponential use on the rehabilitation of degraded agro-silvo-pastoral systems, particularly the Montado/Dehesa, now menaced by shrub invasion and diseases as a result of a poor management and abandon of the system, which is inducing the decay of the valuable cork and holm oak trees.

Another use of this type of mixtures is to cover the soil of certain forestry areas, olive groves, vineyards and orchards, although the mixtures should be adapted to each one of these cases.

Portuguese farmers adopting SBLRPP have already been paid for their environmental service of carbon sequestration in the soil, but due to economic restrictions those payments have been interrupted.

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6. To resume and conclude

In regions influenced by a Mediterranean climate, the rehabilitation of degraded lands to increase their productivity and profitability can be processed through the use of well formulated rain-fed sown bio-diverse legume rich permanent pastures complemented by bio-diverse legume rich forage crops well adapted to the soil and climate conditions of the local where they are growing. This type of permanent pastures are low cost, long lasting, being also an important tool to stop erosion, improve soil fertility, soil water cycle, biodiversity and landscapes, etc.. These pastures have also a high degree of resiliency to eventual phenomena imposed by climate change, such as drought and waterlogging, and provide an important contribution to mitigate the effect of greenhouse gases on climate change, by sequestering large amounts of atmospheric CO_2 in the soil. On top of that, and most important, they offer to rural populations the possibility of staying or returning to their places of origin, taking care of their farms and landscapes, so helping to keep this planet alive.

However, there are some areas of knowledge requiring further research in order to increase the efficiency of this type of pastures, among which we point out: looking for new legume species and cultivars to increase pasture diversity in certain climatic and soil conditions, including those rich in condensed tannins, able to prevent bloating, control gastro-intestinal parasites, and to increase the uptake of protein by the ruminant animal; look also for other plants (herbs) which can play an important role in controlling weeds and providing substances which may improve animal health and condition; looking for possibilities of using certain microbes forming association with pasture plants, such as phosphate solubilizing bacteria (e.g. *Pseudomonas*), nitrogen fixing bacteria in non-legume species (e.g. *Azospirillum, Azotobacter*) and promotors of nutrient uptake, such as arbuscular *Mycorrhizae* which extend the rhizosphere of the plants, all able to improve the nutrition of the pastures at low cost.