Historical development and future perspective of conservation agriculture practices in crop-pasture rotation systems in the Mediterranean region of South Africa

Swanepoel P.A., Labuschagne J., Hardy M.B.

in

Kyriazopoulos A.P. (ed.), López-Francos A. (ed.), Porqueddu C. (ed.), Sklavou P. (ed.). Ecosystem services and socio-economic benefits of Mediterranean grasslands

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 114

2016
pages 75-78

Historical development and future perspective of conservation agriculture practices in crop-pasture rotation systems in the Mediterranean region of South Africa

P. A. Swanepoel[1]*, J. Labuschagne[2] and M. B. Hardy[1]

[1] Department of Agronomy, Stellenbosch University (South Africa)
[2] Directorate Plant Sciences, Western Cape Department of Agriculture, Elsenburg (South Africa)
* Corresponding author email: pieterswanepoel@sun.ac.za

Abstract. The Mediterranean region of South Africa is confined to the south-western parts of the country and is divided into two sub-regions: The Swartland and the southern Cape sub-regions, which receive ca. 80 and 60% of their rainfall in winter, respectively. The original vegetation is classified as lowland coastal renosterveld, which is a short, fire-prone, sclerophyllous shrubland. Renosterveld is associated with fine-textured, low to moderately-fertile, shale-derived soils, with a low natural carrying capacity of 12 to 25 hectares per livestock unit. Ninety three per cent of the area has been transformed to crop and crop-pasture production systems with wheat and other small grains, canola, lupins, lucerne and medics used in various combinations in the rotation. The fodder component of these systems supports mostly sheep farming. The aim of this paper is to provide a synthesis of the challenges and opportunities related to issues involving soil conservation in the Mediterranean region of South Africa. This paper highlights the importance of research on soil quality and conservation agriculture, to ensure sustainability of crop and pasture production. The agricultural and ecological significance of soil tillage, crop rotation sequence, soil organic matter and soil microbial functionality will be discussed.

Keywords. Cover crop – Medics – Organic carbon – Tillage – Wheat.

Histoire du développement et perspectives d'avenir des pratiques d'agriculture de conservation dans les sytèmes de rotation cultures/pâturages dans la région méditerranéenne d'Afrique du Sud

Résumé. *La région méditerranéenne d'Afrique du Sud est confinée dans la partie sud-ouest du pays et divisée en deux sous-régions: le Swartland et le sud du Cap, qui reçoivent respectivement ca. 80 et 60% de pluviosité en hiver. La végétation originale est classée comme 'renosterveld" de plaine côtière, caractérisée par des arbustes buissonnants de sclérophylles. Le renosterveld est associé à un sol à texture fine, presque stérile ou modérément fertile dérivé de schiste argileux, ayant une faible capacité naturelle d'hébergement, à raison de 12 à 25 hectares par tête de bétail. Quatre-vingt treize pour cent de la région ont été transformés en systèmes de pâturages et de champs de plantation de blé et de graines de petite taille, canola, lupin, luzerne et médicago alternés différemment dans des combinaisons de rotation. Les fourrages de ces systèmes sont principalement pour le pâturage de moutons. L'objectif de ce document est d'apporter une synthèse sur les défis et les opportunités ayant trait à la conservation du sol dans la région méditerranéenne d'Afrique du Sud. Il souligne l'importance de la recherche sur la qualité du sol et l'agriculture de conservation, afin d'assurer la durabilité de l'élevage et la production des cultures et des pâturages dans la région. Les pratiques de labour ayant des conséquences agricoles et écologiques, la séquence des rotations, la matière organique du sol et la fonction microbienne du sol seront aussi discutées.*

Mots-clés. *Blé – carbone organique – Culture de couverture – Medics – Labour.*

I – Introduction

South Africa is classified as a dry country. The seasonality of rainfall is determined largely by the sea surface temperatures of the Atlantic and Indian Oceans, and topography. South Africa could broadly be subdivided into three regions in terms of seasonality of rainfall. The summer-rainfall region covers the majority of the country. All-year rainfall occurs in a narrow strip on the southern seaboard. The Mediterranean region is confined to the south-western parts of the country. This region covers ca. 70,000 km^2 (Dallman, 1998). The Mediterranean region is divided into two agriculturally important sub-regions: The Swartland and the southern Cape, which receive ca. 80 and 60% of their rainfall in winter, respectively. Mean annual rainfall varies from ca. 200 mm in the northern parts of this region to ca. 500 mm in the southern and south-eastern parts. Soils in the Mediterranean region are highly variable and shallow (<500 mm deep) with poor drainage, and are prone to erosion and soil surface crusting. Shale derived soils of duplex, podzolic, plinthic, gleyic and lithic soil groups are the most common (Soil Classification Working Group, 1991). These are classified by the IUSS Working Group (2006) as Solonetz, Luvisols, Podzols, Plinthosols, Eluvic, Orthic and Glossic soils.

The original vegetation is classified as lowland coastal renosterveld, which is a short, sclerophyllous shrubland. This forms part of the Cape Floristic Region, which has a very high level of endemism (Goldblatt and Manning, 2000). Lowland coastal renosterveld is associated with fine-textured, low to moderately-fertile soils, with a low natural carrying capacity of 12 to 25 hectares per livestock unit. Due to its inherently low livestock production potential, ca. 93% of the area has been transformed to crop and crop-pasture production systems (Kemper *et al.,* 1999). Although the importance of preserving the natural vegetation for our future generations could not be stressed enough, the rural economies are dependent on the success and sustainability of agriculture. Agriculture will remain central within the current global and regional economic environment as it is primarily responsible for supporting food security. Farmers have come to understand that agriculture should not only be high yielding, but also protect the environment. This means that both sustainability and continuous production from soil should be ensured. Ensuring sustainable agricultural production demands maintaining or enhancing soil quality. The aim of this paper is to provide a synthesis of the challenges and opportunities related to issues involving soil conservation in the Mediterranean region of South Africa.

II – History of cropping systems in the Mediterranean region

The first Europeans established a Dutch colony in the Cape in 1652, as a re-supply point and way-station on the sea-route between the Netherlands and the east. The first farmers were given land by the Dutch East India Company (VOC) to produce wheat. The VOC had the rights as the only legal purchaser of wheat and fixed the wheat price. The farmers took out three-year loans from the VOC for purchase and repair of equipment need for farming operations. Wheat was the only commodity accepted for the repayment of debt to the company. Wheat production was further stimulated through legislation which gave the VOC exclusive rights on the selling of other farm produce. Therefore, initial expansion of farm land was driven by wheat production systems, and not for expansion of grazing lands as normally occurred with colonisation of other countries. During the 1800s and 1900s, increasingly more Europeans flocked to the Cape which provided further impetus to expand wheat production. Import tariffs on grain products were doubled in 1920s, which led to increased areas and over production. The first and second world wars, and later on, isolation from the global economy due to apartheid, encouraged political interventions which supported wheat production to ensure self-sufficiency for the country. These interventions encouraged expansion into areas of marginal production potential. Until the 1980s, wheat was cultivated mostly in monoculture, and yields declined through time. The Western Cape Department of Agriculture subsequently promoted crop rotation systems and subsidised seed, lime and planting operations to establish annual *Medicago* species. This has increased sheep production, as the foraging component of these systems improved. Deregulation of the agricultural economy in the 1990s required major changes to farming system. Most marginal lands were removed from cereal production and, from early 2000s, most farms have converted to conservation agriculture (CA) systems. Currently, pasture and/or cover crops play an integral role to ensure economic sustainability of these cropping systems.

III – Conservation agriculture systems

Conservation agriculture can be viewed as a combination of management practices that ensure more sustainable agriculture and include reduced tillage, residue or cover crop management and crop rotations (FAO, 2015). The majority of grain producing farmers in the South African Mediterranean region have adopted minimum-tillage and crop rotations. The cropping systems are based on wheat, barley, oats and canola. These cash crops are cultivated in rotation with lupins, clovers, lucerne and annual medics. Inclusion of cover crops, with prominent root systems, as organic carbon (OC) builders are also widely promoted. However, the most important source of OC, namely the root systems, needs more research attention.

Research in the Mediterranean wheat producing region has shown that the effect of tillage differs between its two sub-regions. The hot and dry summers in the Swartland are not conducive to rapid OC build-up. In this region undisturbed Renosterveld has OC content of ca. 1.8%, whereas the OC content in cultivated lands range from 0.2 to 1.2%. In the southern Cape region OC contents of Renosterveld may be in excess of 3.0% while that of cultivated soil varies between 1.0 and 2.5%. The comparatively high concentrations relative to the Swartland could be ascribed to the differences in rainfall distribution. Two long-term trials evaluating tillage practices along a gradient of soil disturbance were conducted in the Swartland and southern Cape regions. The low OC concentrations of cultivated soil in the Swartland renders the soil with low buffer capacity against practices that tend to degrade soils. Within six years after introducing conventional tillage to what used to be a reduced tillage regime, active C in the Swartland was reduced ($P<0.05$) from 619 to 522 mg kg^{-1}. This effect continued with time, and became more pronounced. Conversely, buffer capacity of the soils in the southern Cape are improved as a result of the elevated C content. Active C in this region was not affected by soil disturbance. Similar responses were recorded for aggregate stability. The study also showed that microbial diversity and activity is lower in the Swartland than the southern Cape. Conventional tillage resulted in the lowest microbial activity and diversity at both sites.

Crop rotation is one of the three principles of CA. Although difficult to achieve, the ideal should be to include three or more non-related crops in the system. Inclusion of a legume is of absolute importance for both reducing nitrogen input costs and ensuring optimum C:N to stimulate N mineralisation and microbial diversity and activity. Optimum soil C:N can be achieved by carefully selecting legumes (low C:N) and crops with a high C:N in a crop rotation system, some of which are managed as cover crops. Due to the activity in the rhizosphere, living roots must occupy the soil for as long as practically possible. Cover cropping could be a viable option in the southern Cape where it can be cultivated in sequences between cash crops. There is an urgent need for a legume cash crop to be included in short-term cash crop systems to replace unproductive lupin especially in the Swartland and southern Cape. The aforementioned long-term trials showed the negative effect of lack of crop diversity as wheat monoculture resulted in the lowest microbial diversity and activity. The effect of crop rotation was however less drastic on active carbon and aggregate stability compared to soil disturbance as a result of tillage.

IV – Challenges and opportunities

The advantages of CA in the Mediterranean region of South Africa surpass the disadvantages and it has therefore become a dominant management approach to manage cropping systems. However, there are still a number of specific pressing concerns and challenges experienced by farmers in CA systems in this region. Since the soils are prone to surface crusting and compaction, efficient establishment of crops without soil disturbance is a challenge. Currently, farmers rely on tine openers. However, due to the success with disc openers especially in South America, the interest in planters using disc openers is increasing. Moreover, minimum-tillage has led to increased OC levels which are skewed to the soil surface (Swanepoel *et al*., 2015). This might have a significant impact on the quality of the seedbed, which may lead to easier establishment of crops. To date, the effectiveness of preparing a seedbed with a tine has not yet been compared to placing seed directly in the soil using a disc on soils that have increased OC level due to several years of continuous CA practices. Elsewhere in the world, such information is also lacking, especially in terms of assessment of microbial activity, which might be stimulated by limited disturbance with a tine, but less so when a disc is used.

Cultivating pasture or cover crops all year round is challenging in the Mediterranean climate, since hot, dry summers do no not support crop growth, especially in the Swartland. Soil in summer and autumn months are consequently covered only by stubble material from the previous annual crop. Often, insufficient material is retained, which expose the soil to direct sunlight, rain-drop impact and microbial degradation, which encourage surface crusting, soil erosion and compaction. Establishing annual crops during the summer months is not a common practise, due to insufficient soil moisture and since any soil water present must be stored for autumn plantings. However, lucerne is used in the southern Cape region where its deep root system is able to survive the dry summer months. In these systems, some farmers experience a decline in soil quality, due to the sparsity of aboveground biomass and hoof-impact of sheep. More research is required to evaluate the effects of long-rotation of lucerne on soil quality in these crop rotation systems, as it is not clear whether the lucerne varieties used are most suitable to ensure good soil health. Similarly, residual herbage of annual medic pastures, produced in the cool season, is utilized by sheep during summer. All material is often removed, which exposes the soil to the extreme temperatures that occur during the summer months. Guidelines for grazing and forage conservation need to be established that ensure the retention of residual herbage during summer towards promoting an improvement in soil quality, without compromising the livestock component of these systems. Furthermore, there is a need to introduce new pasture and cover crops to enhance OC levels deeper into the soil profile.

Fertiliser and lime guidelines for these cropping systems were developed in the 1960s when the soil was still conventionally tilled. With adoption of minimum-tillage and CA, the soil has undergone significant changes in terms of organic matter build-up and distribution of nutrients, which is skewed towards the soil surface. The top soil has been altered physically, chemically and biologically. Active and stable proportions of C have increased, along with microbial and mychorrizial activity. However, after the changeover to CA, the same lime and fertiliser guidelines that were developed for conventional tillage systems were still followed. Guidelines must be re-assessed to ensure sound CA-based crop and crop-pasture production systems.

Acknowledgments

Mr. John Kadende is thanked for translating the abstract to French.

References

Dallman, P. R., 1998. Plant life in the world's Mediterranean climates: California, Chile, South Africa, Australia, and the Mediterranean basin. Univ of California Press.

FAO, 2015. What is Conservation Agriculture? Conservation Agriculture website of FAO, http://www.fao.org/ag/ca/1a.html

Goldblatt P. and Manning J., 2000. Cape Plants: a conspectus of the Cape Flora of South Africa. Strelitzia 9. National Botanical Institute and Missouri Botanical Garden, Cape Town.

IUSS Working Group., 2006. *World reference base for soil resources*, 2nd edition. World Soil Resources Report 103, FAO, Rome.

Kemper J., Cowling R. M., and Richardson D. M., 1999. Fragmentation of South African renosterveld shrublands: effects on plant community structure and conservation implications. In: *Biol. Conserv.*, 90, 103-111.

Soil Classification Working Group, 1991. Soil classification: a taxonomic system for South Africa: memoirs on the agricultural natural resources of South Africa No. 15. Department of Agricultural Development, Pretoria, South Africa.

Swanepoel, P. A., Botha, P. R., du Preez C. C., Snyman H. A. and Labuschagne J., 2015. Managing cultivated pastures for improving soil quality in South Africa: Challenges and opportunities. In: *Afr. J. Range For. Sci*. 32, p. 91-96.