Better integration of crop-livestock system supports promoting Conservation Agriculture in mixed crop livestock system in rainfed drylands: Lesson learned from CLCA project in North Africa

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1. Introduction

Most farming systems in North Africa are dominated by traditional subsistence agriculture and smallholder farms run by multigenerational families. Livestock plays a key role and contributes a significant share to food security and incomes in the region. Smallholder farmers also consider livestock as a primary asset easily converted into cash in dry years. Livestock farming is however characteristically interrelated with cropping systems through weedy fallows, residue, and stubble grazing and the use of woodlands and rangelands (Magnan, 2015; Moujahed et al., 2015). Hence, the food, nutrition, and livelihood security of rural populations in the region largely depends on both crops (mostly cereals and trees) and livestock, with preference given to livestock due to its high and multiple contributions to incomes and assets. Most of the subsistence smallholder farmers of North Africa live in drylands where their crop-livestock systems are rainfed making them more vulnerable to limited and increasingly unpredictable and variable rainfall. In such a production environment, crop productivity and biomass are typically low, due to drought stress and low levels of inputs. Poor land management, namely, continuous cereal monocropping, intensive soil tillage and overgrazing have further degraded land through soil erosion and loss of soil organic matter. Moreover, an increased frequency of droughts, floods and other climatic risks in recent years has further exacerbated abiotic stresses in rainfed drylands.

Conservation Agriculture (CA) principles, including minimum mechanical soil disturbance or no-tillage, permanent soil cover with crop residues and/or cover crops, and crop diversification through varied crop rotation, sequences and associations have proved to be key intervention for enhancing crop productivity, soil health and improving resource-use efficiency in drylands (Bahri et al., 2019; Devkota et al., 2022; Kassam et al., 2019; Mrabet, 2011). Improved soil moisture and nutrient availability under the CA system can improve crop yields by 20-120% in the dry Mediterranean climates of different continents (Fernández-Ugalde et al., 2009; Mrabet et al., 2012). Although there are several benefits, adoption of CA in the region is quite low. Overgrazing of crop residues in open grazing systems is however one of the barriers for the wider adoption of the CA in these mixed crop livestock system (Devkota et al., 2022) as retaining crop residue compete with feed for livestock. Hence, wider and sustainable adoption of CA in mixed crop livestock system needs better integration of crop and livestock in CA-based system.

2. Methodology

In order to inform and promote better integration of crop-livestock systems, while adopting conservation agriculture with national partners in the public and private sector, ICARDA set up an IFAD funded project on Crop-Livestock integration under Conservation Agriculture (CLCA). This initiative was initiated in North Africa and other similar regions in 2015 to assist in the sustainable intensification of the crop-livestock system. This paper highlights options generated, tested, and scaled by CLCA for better integration of the crop-livestock system under CA in Algeria and Tunisia. Some of these practices are diversifying cereal monocropping by introducing food and forage legumes; integrating alternative grazing/feeding systems; integrating tree-crops and livestock in order to effectively address the crop residue tradeoff between providing feed for livestock and leaving residues as mulch.

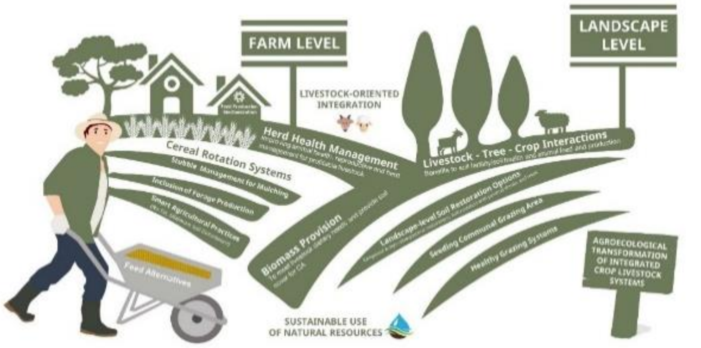

Figure 1. Clustering Crop-Livestock Integration (CLI) Options based on the scale of implementation and resource-orientations (Source: Rekik et al., 2019).

3. Result and discussions

3.1 Increase grain and biomass productivity through better crop management (reducing yield gaps*): to reduce pressure on grazing residues*

Most of the currently cultivated field crops in the small mixed crop-livestock systems of North Africa are cereal forages such as barley, oat, and triticale. Similar to other cereal crops, forage crop yields are exceptionally low compared to what can potentially be achieved (Rekik et al., 2019). The existence of large attainable yield gaps for major food crops indicates an opportunity to increase the average farmer's yield through the adoption of good agricultural practices (Devkota and Yigezu, 2020). Adoption of good agriculture practices not only increases the crop yield but also increases the quantity and quality of grains and biomass produced. This will, in turn, help to satisfy the feeding quality and requirements of livestock in these mixed systems. Use of improved varieties, quality seed, balanced fertilizer application, timely weed management, and legumes in cereal monocropping are considered major determinants for closing the yield gaps in rainfed wheat in Morocco (Devkota and Yigezu, 2020), for example.

3.2. Introduction of forage crop species in the rotation system to increase the quality and quantity of forage

Growing forage crops for direct grazing, conservation or as cover crops has an important role in agronomic sustainability and livestock production in a mixed crop-livestock system. The inclusion of forages in a cereal-based livestock system improves livestock production, enhances soil health and biodiversity, increases carbon sequestration, and minimizes disease infestation, and economic risk through diversifying the cropping system (Christiansen et al., 2015). Several possible forage combinations were evaluated in different production environment and crop mixtures ("triticale + vetch", "oats + vetch", etc.) were included in crop rotations and were introduced as highly suitable alternatives in marginal wheat-based systems (Cheikh M'hamed et al., 2016). In fact, increasing forage production reduces grazing pressure on residues during the summer. For example, when several alternative forage species (Vicia sativa (Vetch), Medicago sativa (Lucerne), Hedysarum citinarium (Sulla) and forage crops mixtures ("triticale 40% + vetch 60%"; "oat 30% + vetch 70%"; "triticale 30% + vetch 70%") were introduced among farmers adopting CA in Northern Tunisia forage production was increased by 4 to 12 t ha^{-1} depending on the bioclimatic zone (Abidi et al., 2020, 2019; Cheikh M'hamed et al., 2018; Rekik et al., 2019). In addition, the fodder was of high nutritional value, adequate for maintaining an intensive production system for dairy products and small ruminants.

However, a lack of quality seed of improved forage varieties, poorly functioning seed and fodder markets, and biased national policy towards the production of strategic (cereal) food grains constrain the economic incentives for sustainable forage production and marketing. Additional non-technical solutions are needed to facilitate farmers' access to forage seed, technical skills and other related services that allow them to enhance their crop rotations and satisfy their flock feeding requirements. Redirecting subsidies on forage crops, for example, has provided successful outcomes for smallholder crop-livestock producers in various Mediterranean countries (Demir and Yavuz, 2010; Lloveras et al., 2004). Developing farmers capacity for seed multiplication in addition to related skills, and providing machinery for seed cleaning and packaging was also found to be effective for upscaling forage integration in Tunisia (Rekik et al., 2019). Thus, public funds should be invested in supporting forage-based crop-livestock farming and related research, including forage and legume seed systems, rather than cereal monocropping or industrial-scale meat and milk production.

3.3. Substantial grazing: optimizing residue to retained and grazing duration and grazing duration

The practice of retaining crop residues under CA creates a conflict of interest between mulch for that can cover the soil surface and stubble grazing for livestock, especially during the summer period. Trade-offs between the use of stubble for livestock feeding or for covering the soil must therefore be resolved, particularly in drylands where fodder potential is low. Under the framework of the CLCA project, ICARDA developed a stubble grazing model (30:30 model) in Tunisia in order to give farmers adopting CA some solutions for reasonable stubble grazing during the summer period (Guesmi et al., 2019; Moujahed et al., 2015). The "30:30 pattern" was developed based on a stocking rate of 30 animals per hectare, during a 30-day stubble grazing period (Fig. 2.). This pattern allows for the retention of adequate crop residues (mulch) in the soil surface (more than 0.4 t ha^{-1} of residue in the soil surface or 40% of the initial biomass of residues on the soil surface) and at the same time as preserving the health body conditions of animals.

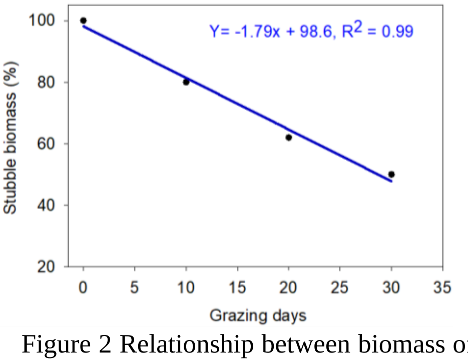

Figure 2 Relationship between biomass of residues (%) on soil surface and grazing duration (day) Source: Rekik et al. (2020)

3.4. Extending crop growing period through better crop choice and crop management practices (relay intercropping)

Better crop choices for example short duration and low water requiring crops and management practices (paired row planting and relay intercropping) can provide the opportunity for harvesting two crops while extending the growing season in favorable rainfed drylands. With two crops harvested from the same piece of land not only increase productivity but also increase the total biomass production for livestock. For example, paired row seeding of lentils during winter and relay intercropping of low water requiring crops such as barley or grass pea and sorghum (as spring planting) increased system productivity without compromising main winter crop (lentil) yield. At the same time, it has provided additional 7-8 t ha-1 fresh biomass for livestock.

Conclusion

This paper provides some evidence and key figures illustrating importance of better integration of crop livestock systems for wider adoption of CA at scale under mixed crop livestock system. Key integrating factors for the sustainable intensification of crop-livestock systems include alternative grazing/feeding systems, crop diversification, integration of tree-crops and livestock, residue management which balance the tradeoff between leaving residues as feed for livestock and leaving them as mulch for the soil, scale-appropriate mechanization, and herd health management. Combining all or a few of these components in CA-based system helps to improve overall farm incomes, crop productivity, soil quality, input use efficiency, and the provision of healthy protein in the human diet, and fodder for livestock consumption. Integrating livestock into cropland also provides the potential advantages of a sustainable intensification strategy.

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