Small ruminants grazing regime as a sustainable management practice for Western Australia Wheatbelt cultivated lands.

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Abstract
The global warming process is leading to increased uncertainty of the rainfall timing duration and distribution. One of the most sensitive crops is wheat, which takes a central place in WA economy. This uncertainty requires investments into supplementary irrigation aimed to ensure wheat growth. An additional important agricultural branch is the small ruminant (SR) breeding, which is been considered a land competitor to wheat breeding. Recent studies from the Negev on loess plain, wadis areas, and rocky grounds demonstrate the positive influences of controlled SR grazing on crop breeding. Three mechanisms were defined for this influence: (i) The trampling' lateral force accelerates the vegetal material digestion into soluble nutrients and resulted in soil fertility, (ii) and increases the soil water holding capacity. (iii)The SR excretion spreading has a dramatic influence on soil fertility and may be used as a land management tool. Intensifying these mechanisms may increase the soil buffering ability for better combating the rainfall uncertainty in WA cultivated lands.

1. Keywords
Wheat breeding, Wadis area, Animal trampling, Manure management practices, rainfall distribution

2. Introduction

2.1 Grazing

Small ruminants (SRs) breeding in Australia is dealt mostly regarding the direct economic gains from milk and meat production. Nevertheless, the grazing action has an indirect influence on land fertility, which has been described as ecosystem destructive management due to the use of intense grazing regimes (Herbel and Pieper, 1991). These contradictory attitudes lead to opposing allocation of open-lands to ranging and, with preference given instead to crop breeding (Zhang et al. 2012). Nevertheless, the influence of controlled and moderate grazing on the ecosystem is poorly studied. The SR interacts with ecosystems via vegetation consumption, trampling, and excretion spreading. The influence of each mean on the ecosystem is affected by grazing timing and duration, herd size relative to the rangeland, soil profile and land outlines, and the herder social patterns (Mor-Mussery et al. 2019). The intensity of the correlation between the animal and the ecosystem per each mean has a parabolic shape based on the 'Intermediate Grazing Optimisation'- IGO model. In this case, the preferred state for the human- 'the optimal threshold' is before the plateau (Doole and Romera, 2013), Fig. 1A.

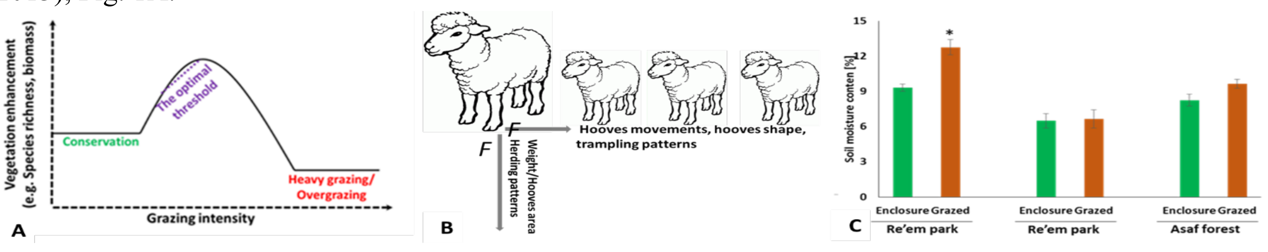

Figure 1. The influence of the animal trampling on soil (A-'Intermediate Grazing Optimisation'- IGO model and the optimal grazing intensity, B- Schematic description of the lateral and vertical forces of the trampling, B- Influence on soil moisture). Enclosure- a fenced area of 20X20m without grazing, Grazed- Adjacent SR grazed area

Most of the studies analyzed the suitability of the IGO model to the vegetation consumption mean, less on the animal' excretion and the animal trampling (Mor-Mussery et al. 2019). The influence of animal trampling on the ecosystem is a relatively mysterious issue and is mostly treated regarding cattle with high grazing intensity and high hoof pressure, which resulting soil compaction, a dangerous soil physical state that increases the antagonism in the public against the ruminant breeding. Nevertheless, in Australia and all over the world additional bred animals is common, such as SR. Their influence on the soil is not well studied, although evidence was given by researchers such as Lal (2006). Nevertheless, mechanism/s, which correlates the grazing regime and the influence on the ecosystem, is missing.

2.2 Wheat breeding and the Wheatbelt in Western Australia

The Australian continent is characterized by extreme climate events such as long heatwaves, droughts, and tropical storms, resulting in widespread bushfires and temporal variability in rainfall, especially in winter that is the main growing season for wheat in WA (Bell et al., 2011). The inconsistency of the rainfall in the winter, the wheat growing season harms the plant growth and yield. To breed wheat in this state the farmer is required to implement cultivations such as deep tillage using heavy machinery, needed for high amounts of fertilization and chemicals for pest control, resulting in soil compaction, salinization, erosion, and incision (Hamza and Anderson, 2005).

2.3 Geomorphological patterns of WA Wheatbelt

The WA wheat belt is located in the semiarid to arid regions. This region is characterized, by heterogeneous rainfall events distribution over the winter, with a high rate of events characterized by high intensity leading to soil erosion and salinization (Hatton et al., 2003). The geomorphology of WA Wheatbelt has been mostly affected by vegetation cleaning between 1940 and 1970 for agriculture, leading to a dense network of ephemeral streams similar to the gullies phenomena in arid regions. Nevertheless, due to the different soil profile patterns in the WA Wheatbelt, which is expressed by the existence of the fine particle layer as 1m below surface and lack of organic matter, there is intense water recharge, leading to salinization (Rengasamy, 2006).

2.4 Study hypothesis and aims

The study hypothesized that similar to the vegetation consumption, the IGO model may suit the SR trampling mean. Therefore, supplying the adequate grazing regime parameters in WA cultivated lands, and even of degraded ones, may enhance the soil rehabilitation and assure consistent yield supply even in highly heterogeneous rainfall patterns. Therefore, the objective of this planned study was to define these terms for WA wheat-belt cultivated lands.

3. Tools and Methods

3.1 Review of recent studies from the Negev

As previously stated, the connectivity between the seasonal streams in WA Wheatbelt and their surrounding cultivated lands is similar to other regions worldwide as the loess plateau in China and northern Negev loess plains (Mor-Mussery and Laronne 2020). Therefore, previous knowledge from these regions can be used to design a suitable solution for WA Wheatbelt cultivated lands. Hereby new insights from studies in the northern Negev will be reviewed and adaptions to WA soil will be suggested.

3.2 Planned study

The study is planned to be carried out in two farms located in WA semiarid and arid regions. In each farm, nine fields (three grazing regimes: conserved, semi-grazed, and grazed*, each treatment- three replicates) will be located. Wheat will be bred similarly on all fields based on the common WA wheat breeding scheme (Cato and Mullan, 2020). In each field, two 1m Drill and drop multi-depth soil moisture probes will be installed giving volumetric soil moisture content (VSC) and salinity data from the surface until 1m depth each 10cm, each hour. All probes will be connected to a central data logger and energy supply.

The SR grazing sets will be carried out in the fallow season to focus on the trampling influence on soil (Balaya et al. 2014). The VSC, Salinity and additional fertility, physical soil data achieved by infield measurements, and NDWI* will be used to determine the mechanism that correlates the trampling and soil patterns

*The Normalized difference water index (NDWI) data will be calculated from drones and Landsat® (or other) satellites imaging.

3.3 Designing appropriate grazing routes over the cultivated lands for assuring homogenous distribution

In each agriculture utilization, manpower is the most influential factor on profitability. Therefore, to save manpower different routing ways will be analyzed to assure a homogenous distribution of the SR over the field. Two issues will be analyzed, defining the routing needs of the herd according to the land topography and training the bellwether goat for herd leading (Smith et al. 2014).

4. Literature review

Studies from the northern Negev indicate that the trampling force of the animal can be divided into vertical and lateral forces. The animal weight is influencing the vertical force, which for large ruminants can reach to 7Kg cm^{-2} of 1cm^2 hoof and for SR it 3Kg cm^{-2} (Yang et al. 2019), Fig. 1B

In addition, due to behavioral patterns, the big ruminant has a high tendency for centralized herding (surrounding hot plots), while the small ruminants tend to more distributed herding. Both patterns lead to a higher tendency of soil compaction after big ruminant herding than small ruminants. In addition, Mor-Mussery et al. (2020) found on loess plains that SR herding enhances the cutting of standing biomass into a litter and its' further digestion to soluble nutrients and organic matter by increasing the soil wetness, which enhances the bacteria film formation (Mor-Mussery et al. 2020), Fig. 2A. Another study by Mor-Mussery et al. (2021) indicates that the SR ants grazing in the wadies area may rehabilitate the whole area by forming feedback fertility loops of their excretion with the wadi channel, leading to upslope expansion of fertile sediments layer. This layer stabilizes the wadi slopes and increases their fertility and vegetation productivity (Fig. 2B). This study also demonstrates three herding patterns of the small ruminants (based on analysis of their dropping location and data from the herd owners) as follows: a homogenous one when the animals grazed freely, route, when the animals been led by the shepherd or bellwether goat and centralized over hot spots as puddle or tree for browsing when these plots exist and free grazing allowed (Mor-Mussery et al. 2013).

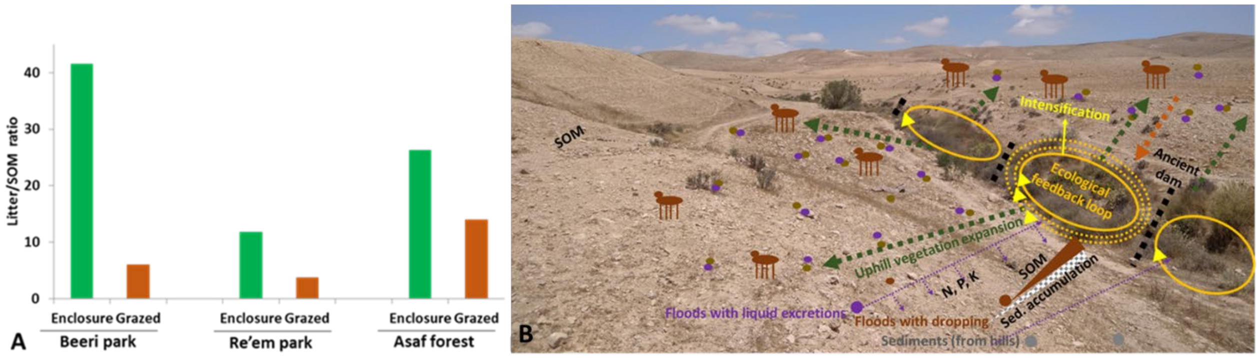

Figure 2. The influence of grazing on soil fertility (A-The influence of trampling; B- Floods with liquid excretion enrich the wadi channel with nutrients and organic matter leading to sediments accumulation and forming a productive soil layer that expands uphill and resembles land rehabilitation)

5. Discussion and challenges for implementation in WA Wheatbelt

Physically, SR trampling influence is similar in all the types of soil profiles by increasing the assimilation of organic matter in the soil (e.g., Mor-Mussery et al. 2020& 2021). Nevertheless, the infield influence depends not only on the trampling itself but on the existent soil profile and character. Therefore, land managing as SR grazing regime has to consider the differences in soil profile and patterns. A highly challenging pattern characterizing WA cultivated lands is salinization, which has to be considered regarding also regarding SR grazing regime (Murphy, 2015). The second noticeable challenge is to suit the finding of studying one goat type in one region to other types. While in Israel and whole the Mediterranean region the bred type are the Baladi and Jabali types, which are suited to the mountains region (Haseen et al. 2016), in WA the common bred type is the Boer (Malan, 2000). The third challenge is to assure a homogenous spreading of the goat in the pasture lands. Two methods can be used, based on the finding from the Negev studies, training bellwethers goats (Peischel and Henry, 2006), and designing plantation of native Australian rangeland trees with grazing, browsing, or shading importance as the *Acacia victoriae* **(Fig. 3).**

Figure 3. The *Acaicia victoriae* forms a productive soil patch for grazing, pods, and leaves for browsing

The outcome of these ways has to be continuously analyzed by monitoring the herds' location in the cultivated lands. Other parameters that affect the influence of grazing on cultivated lands are summarized in Mor-Mussery et al. (2019).

Conclusion

Not only is grazing an important management practice for the cultivated lands of WA wheat-belt, but it also can rehabilitate degraded ones and assure sustainable agriculture utilization of wheat by increasing the soil buffering ability to the inconsistent rainfall events. Nevertheless, studies have to be carried out to define the accurate rate to prevent damage to the ecosystem.

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