

Changes in Soil Organic Carbon, Nitrogen and Phosphorus in Modified and Native Rangeland Communities (Case study: Sisab Rangelands, Bojnord)

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Abstract. Converting the native rangelands to simplified agronomic communities causes some changes in soil carbon, nitrogen and phosphorus. Establishing of perennial plant communities on formerly cultivated rangelands is expected to stabilize soil properties and increase the amount of C, N, P stored in rangeland soils, but there is little information on what plant communities are the most effective for improvement of soil C, N, P reserves. The purpose of this study was to compare soil C, N, and P pools in ungrazed native rangelands with plant community of *Festuca-Centurea* with those ungrazed pastures established by sowing non-native perennial grasses (*Agropyron elongatum* and *Agropyron desertorum*), shrubs (*Kochia prostrata*), and wheat cultivation in continuous dry land farming system. Study site was located in Sisab Research Station in North Khorasan Province, Iran. The results showed that the total C, N and P contents in the soils under modified plant communities were less than that for native rangeland. Soils under *A. elongatum*, *A. desertorum* and *K. prostrata* tended to have higher values for total C, N and P than soils cultivated annually in wheat-fallow systems. The total C and N content of soils under *K. prostrata* were near as native rangeland which suggests that *K. prostrata* can increase the soil C and N contents much more rapidly than the other perennial communities.

Keywords: Modified Rangeland, Native Rangeland, *Kochia prostrata*, Perennial grasses, and Soil properties.

Introduction

The effects of converting native rangelands to simplified agronomic communities on soil carbon, nitrogen and phosphorus are expected to differ over the short-term (Dormaer and Willms, 2000). A considerable portion of the rangeland in the North Khorasan Province, Iran was cultivated for agricultural use in the last 50 years causing reduction in the soil organic C pool (Dianati Tilaki *et al.*, 2010). Intense cultivation disrupts soil aggregation and fragment organic matter, accelerating decomposition, increasing microbial activity and stimulating the emission of CO₂ from the soils (Anderson and Coleman 1985; Burke *et al.*, 1995). The C input from agricultural crops is generally lower than rangeland plant communities, because more of the above-ground biomass may be removed from the ecosystem and also annual crops produce less root biomass than perennial grasses (Burke *et al.*, 1995). Management practices that stabilize soil properties and promote primary production in rangelands are expected to sequester more C and reduce CO₂ emissions.

The establishment of permanent cover on formerly cultivated lands can quickly stabilize some soil properties, increasing water retention and reducing the quantities of sediments, nutrients and agrochemicals transported to surface waters within a few years (Dunn *et al.*, 1993). It seems to take much longer for soil chemical and biological properties to recover after cultivation ceases. Dormaer and Smoliak (1985) reported that it took more than 50 years for the soil organic C content of abandoned cropland to approach the level of native rangeland. Five years after establishment of permanent grass cover, Gebhart *et al.* (1994) observed a 21% increase in soil organic C content in the 5 to 10 cm soil depth, but there was

significantly less organic C in formerly cultivated land than native grasslands. In the first 10 years after converting cropland to grassland, Baer *et al.* (2000) found no change in the total C and N pools, but they found an increase in microbial biomass C and N pools. Total C and N, microbial biomass and mineralization potentials were lower in the recently established grasslands than native grassland. If one hopes to increase C pools on formerly cultivated lands such as North Khorasan rangelands, he must first understand how cultivation has altered soil chemical and biochemical properties and then determine what management practices will be most effective for building the soil organic C, N and P reserves.

The hypothesis of this research was that the reserves of total C, N, and P would decline after cultivation relative to native rangeland, but the decline would be lower in plots that were planted with perennial plants than those plots cultivated repeatedly for annual crop production. The objective of this study was to compare selected soil properties of modified plant communities (monocultures of annual agronomic crops, perennial introduced grasses or introduced shrub) with native plant communities in an ungrazed, unfertilized rangeland soils in the North Khorasan Province, Iran.

Materials and Methods

The study was conducted in Sisab Research Station, Bojnord, Iran that is representative of major ecosystems of the North Khorasan Province. Prior to the establishment of the research station in 1986, the range areas were being grazed heavily and there was no record available of cultivation for the area (Fig. 1).

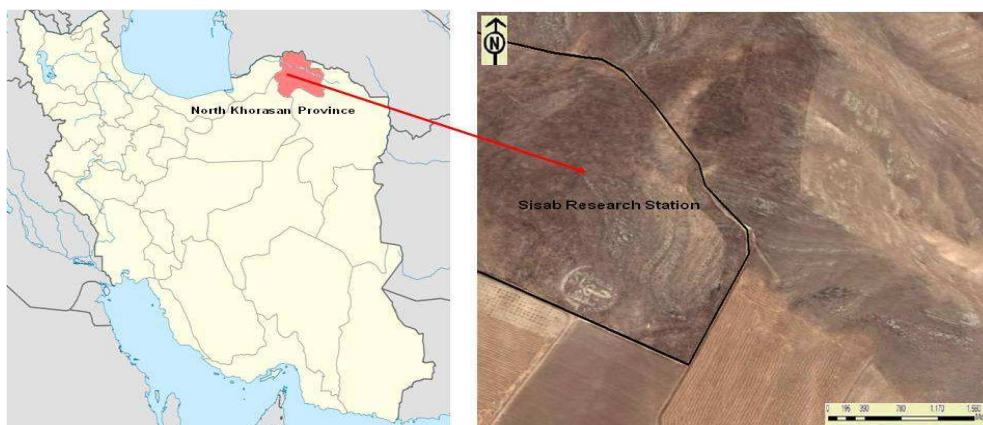


Fig. 1. Location of the study area in Iran regional map

During station establishment, its borders were fenced and some areas have been protected from sheep and goat grazing for 22 years, whereas these animals have continuously grazed the outside of range area. The soils of station are clay-loam, slightly alkaline and low in organic matter. This area is characterized by its semi-arid climate with 270 mm annual rainfall, cold winters, and dry summers (Naghipour Borj et al., 2009). The major species were *Festuca ovina*, *Centurea depressa*, *Stachys turkamanica*, *Stipa barbata*, *Astragalus sp* and *Phelomis cancellata*.

The total area of this station is 303 ha. From this area, 47 ha were exclosed as native rangeland and 60 to 70 ha were used for pasture establishment.

A complete randomized design was established with six treatments as following treatments:

- 1- Native rangelands.
- 2- Sowing non-native perennial grass (*Agropyron elongatum*).
- 3- Sowing non-native grass (*Agropyron desertorum*).
- 4- Sowing non-native shrub (*Kochia prostrate*).
- 5- Dry land farming by cultivation of wheat-fallow systems.

For each treatments plant biomass and soil were sampled, along with three 100 m long transects spaced at least 30m apart. Transects were laid entirely inside each treatment with 10 plots 1m² along each.

Above ground biomass was clipped to ground level using hand clippers. Root biomass was collected from each sampling plot. Plant biomass was oven dried (60° C for 48 hours), and the root-to-shoot biomass ratio was calculated on a g dry matter m⁻² basis.

The soil data were sampled from two depths, 0-15 and 15-30 cm and five composite samples and collected (each sample is mixed of six samples) from each depth in each area. These depths are commonly used in studies of soil organic carbon and total nitrogen pools (Sombroek et al., 1993; Batjes, 1996).

Prior to laboratory analysis, the samples were air-dried at room temperature. Samples for chemical and physical analyses were passed through a 2mm soil sieve. The bulk density of soil samples was measured by the hunk method (Zarinkafsh, 1993). SOC (Soil Organic Carbon) was determined according to the Walkley and Black method (Gao et al., 2007) while total N was measured by the Kjeldahl method (Elliott, 1986), and total P was determined by the spectrophotometer.

Results and Discussion

Soil bulk density was lower in undisturbed native rangeland than modified plant communities (Table 1). Bulk density declines with increasing soil organic matter content because the quantity of air-filled pore space increases. The highest and lowest root-to-shoot ratios were

obtained in plant communities, Native rangeland and Wheat-fallow, respectively (Table 1).

Table 1. Soil bulk density (0 to 30 cm depth) under native rangeland and modified plant communities and root/shoot biomass ratio in Sisab, Iran.

Treatment	Soil bulk density (g/cm ³)	root-to-shoot biomass ratio
Native rangeland	0.98	2.01
<i>Kochia prostrata</i>	1.16	0.98
<i>Agropyron desertorum</i>	1.20	0.84
<i>Agropyron elongatum</i>	1.12	0.39
Wheat-fallow	1.28	0.20

The total C, N, and P contents of rangeland soils decline upon cultivation and it may take many years for soil nutrient pools to return to pre-cultivation levels (Dormaar and Smoliak, 1985). To determine whether net gains or losses of total C, N, and P have occurred in the soil profile on a kg/ha basis, it is necessary to collect soil samples to perhaps a 2-m depth and determine the nutrient content and bulk density of each soil layer sampled (Lal, 2002). Since we did not collect this information, our discussion will focus on differences in the total and available nutrient contents in the

0 to 30 cm layer of soils under native rangeland and modified plant communities.

The results showed significant differences among treatments for all of traits. Total C and N were lower in soils under modified plant communities than native rangeland. The lowest total C and N contents were obtained in the wheat-fallow treatments (Figs 2 and 3).

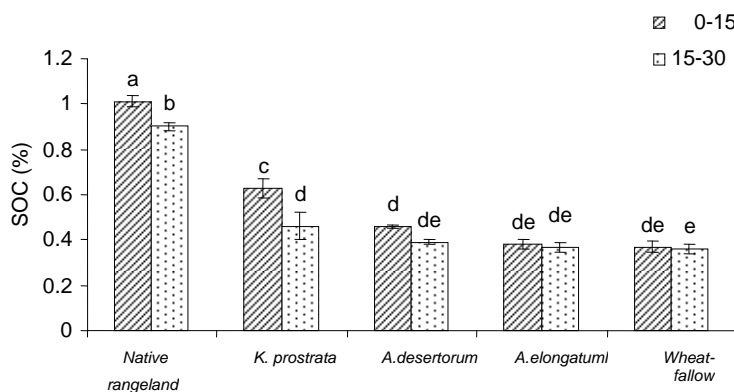


Fig. 2. SOC (Soil Organic Carbon) percent in soils under native rangeland and modified plant communities.

At each sampling date, mean values with the same letter are not significantly different at $P < 0.05$

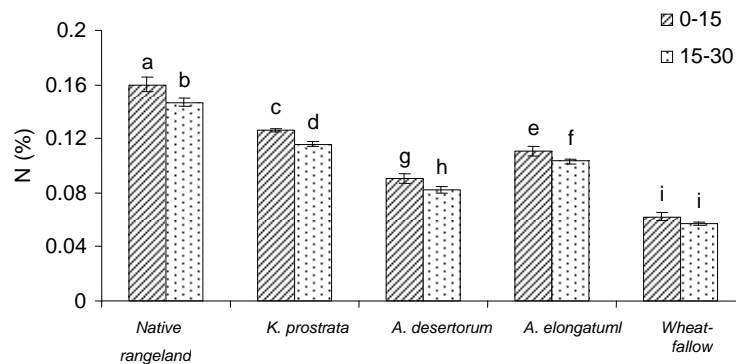


Fig. 3. N percent in soils under native rangeland and modified plant communities. At each sampling date, mean values with the same letter are not significantly different at $P < 0.05$

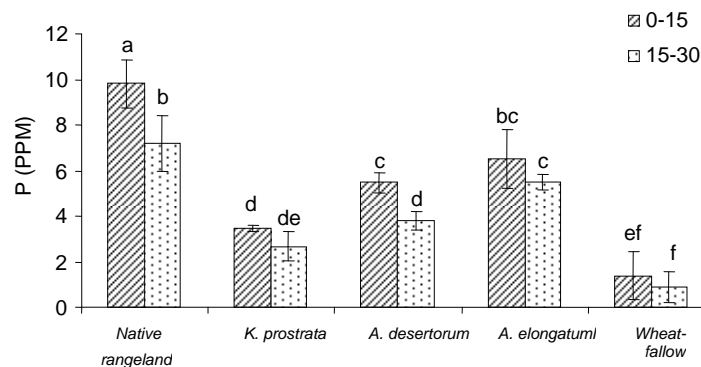


Fig. 4. P concentration in soils under native rangeland and modified plant communities. At each sampling date, mean values with the same letter are not significantly different at $P < 0.05$

The decline in total C and N in the wheat-fallow rotation compared to native rangeland was expected because the fallow phase of the rotation contributes little C through primary production and is cultivated for disrupting soil aggregates and accelerating C and N mineralization (Elliott, 1986, Paustian *et al.*, 1997).

Soils under native rangeland and *K. prostrata* had generally higher total C and N than other treatments (Figs. 2 and 3). The total C and N contents of soils under *K. prostrata* were near native rangeland, which suggests that *K. prostrata* can increase the soil C and N contents much more rapidly than the other perennial communities. There tended to be total C in soils under *K. prostrata* than other modified plant communities suggesting a higher net C input into soils from *K. prostrata*. *K. prostrata* has a higher root-to-shoot ratio than other modified plant

communities (Table 1), and we propose that root production and turnover were responsible for the increase in soil C content under *K. prostrata*.

Organic carbon in depth of 0-15cm was more than depth of 0-30cm in soil. The high quantity of carbon in depth of 0-15cm depended on high content of litter in this depth (Frank *et al.* 1995, Jalilvand *et al.*, 2007).

In addition to high quantity of nitrogen in native rangeland, it was in 0-15cm depth more than depth of 0-30cm of soil. The high quantity of nitrogen in 0-15cm depth was because of nitrogen in soil particularly in surface layer. Therefore, the process of accumulation of nitrogen in soil had direct relationship with organic carbon.

Ahmadi Ilakhchi *et al.*, (2002) in Central Zagros and Yousefifard *et al.* (2007) in Cheshmeh Ali of Chaharmahal Bakhtiari province Iran also concluded that organic

carbon decreases because of land use change of rangeland to agriculture land. Aguilar *et al.* (1988) also reported that organic materials decrease as a result of tillage because of two reasons, disturbance of surface soil and due to accelerate of biologic decomposition of organic materials and intensification of soil erosion following the losing of organic materials with runoff.

The total P content of soil was significantly higher in native rangeland than cultivated treatments (Fig. 4). Only a small proportion of the total P in soils issued for primary production, and it is recycled when plant residues are not exported from the site. Above-ground wheat biomass contains about 0.5% total P (Heyne 1987), and if grain was 45% of the above-ground biomass, then 1.1 to 1.19 kg P ha⁻¹ would be removed from the wheat-fallow treatment at harvest. This estimate was in agreement with Whalen *et al.* (2003) who estimated 4 to 9 kg P ha⁻¹ year⁻¹ for grain and hay from crop rotations in Canada. This finding was also in agreement with results from Elliott (1986) which showed that aggregate fractions contained less C, N and P when soils were cultivated than when they were left under native rangeland.

Conclusion

We conclude that production of annual agricultural crops on rangelands in tillage systems can deplete soil C and N reserves significantly. The establishment of perennial range plants on formerly cultivated land can slow or reverse the depletion of soil C and N reserves. The stabilization or loss of soil C and N from modified plant communities is affected by climate (soil temperature and moisture) as well as the quantity and chemical characteristics of residues produced by plants. Differences in the total P content of soils under modified plant communities and native rangeland appeared to be related to the initial site preparation rather than experimental treatments or environmental

factors. Carbon and nitrogen could be approached to their initial place by *K. prostrata* more than other species.

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