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SHORT NOTE

Ants Visible from Space Influence Soil Properties and Vegetation in Steppe Rangelands of Iran

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Abstract
Messor nests in Iranian steppe rangelands can be so large that they are visible from space. When compared with reference soils, nest soil is higher in nutrients and lower in pH. Ant nests also homogenise the nutrients throughout the upper soil profile, although this effect diminished when nests are abandoned. The denuded circles around nests are surrounded by rings of vegetation that differ in species composition from that of the surrounding vegetation, while abandoned nests are colonized by a different range of plant species. Data on the density and abundance of *Messor* cf. *intermedius* nests indicate that the soil in less than 1% of the area is impacted, although the cumulative effect of so many nests influences the plant species and vegetation structure of the region.The data indicate the importance of these ants in altering soil chemical composition and plant diversity, which could have flow-on effects to the diversity of animals.

Introduction

Information concerning Iranian ant's effects on environment has tended to be sparse or is often published in Iran.This situation is likely to change due to the opening up of the country and removal of sanctions, although a further stimulus is the recent translation into Persian (farsi) and online availability of the book *Ants: Standard Methods for Measuring and Monitoring Biodiversity* (Agosti et al., 2000) by Mahsa Ghobadi and Mohammad Mahdavi (Agosti et al., 2015, down-loadable at https://zenodo.org/record/16183#.Vu-hzlKfSjg)**.**

A recent series of researches published in Iran by Ghobadi (2013) and Ghobadi et al.(2015; 2016) have quantified the influence of one of the most prominent *Messor* spp. on soil properties and vegetation in steppe rangelands of Iran. In view of the importance of this work, we here summarize and synthesise the findings of these two papers in order to bring them to the attention of the wider readership.

The study

Harvester ants from the genus *Messor* count among that selected group of invertebrates whose manifestations are clearly visible from space by satellite imagery (Fig 1). The study was performed in a 30 ha site near Roodshoor, Saveh, Iran, located at a point 60 km along the Tehran-Saveh highway (35.43802° N; 50.89633°E) in an area from which sheep and goats had been excluded for 40 years. The vegetation is a chenopod steppe shrubland whose dominant plant cover includes *Artemisia sieberi* and *Stipa hohenackeriana*, along with *Salsola tomentosa*, *Brassica deflexa*, and *Poasinaica* as co-dominant species (Mahdavi et al., 2009).

Prominent ant nests were visually located, mapped and measured along ten 200 m long transects. Identification of ants was mainly to species group, since the taxonomy of Iranian ants has not been fully defined. Voucher specimens of these species are deposited in the Naturhistorisches Museum, Bern, (Code NMBE http://grbio.org/cool/5hwi-0wgz).

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Fig 1. Location of the study area at Roodshoor, Saveh, Iran, showing location of *Messor* cf. *intermedius* ant colonies (light circles like the one in the red square). (Photo courtesy of Google earth).

The species recorded represented three genera (*Messor* (3 species), *Cataglyphis* (3 species) and *Formica* (1 species) (Table 1). Other ant species with more cryptic nests may also be present, but *Messor* cf. *intermedius* had by far the largest (mean diameter 2.3 m, modal diameter 3.5 m) and most abundant nests (Table 1), which were flat and circular in shape, as evidenced by the light circles in Figure 1. Some of the nests of this species were abandoned, but still visible (Fig 2).

The study measured soil physical and chemical properties on 18 live and seven abandoned ant nests and also in un-nested control areas 3 m away from the live nests of *Messor* cf. *intermedius*. Chemical properties were measured at four depths and averaged across nests. Active mound soil has a significantly lower pH than controls (Table2) and significantly higher levels of nitrogen, phosphorus, potassium, magnesium, calcium, organic matter and carbon and electrical conductivity (Ec) (Table 2). Percentage sand was higher on active ant nests than on controls but percentage clay was lower. Soil temperatures were significantly higher on ant nests than control areas in both dry and humid seasons, as was soil moisture. Water infiltration, as measured by timing water in cylinders to percolate into soil, was significantly higher on ant nests in both dry and humid seasons (Table 2). None of the chemical or physical soil properties differed significantly between abandoned nests and control areas (Table 2), indicating that it had been the activity of ants that was responsible for the differences observed on active nests.

Table 1. Properties of ant species found in the study site.

Species	Functional group	Typical Habitat	Color	Size	Mound shape	Density (no./h)	Mound Diameter mean (m) ±SE	Material composition
Messor cf. *intermedius*.	Harvester	Dry areas	Black	Small & Medium	Flat	8.3	2.3± 0.03	Seed, Plant, Soil
Messor cf. *subgracilinodis*	Harvester	Dry areas	Black & Red	Medium	Dome	0.9	1.46± 0.10	Seed, Plant, Soil
Messor cf. *structor*	Harvester	Dry areas	Black	Small	Pore	0.1	-	Soil
Cataglyphis bellicosus	Scavenger	Steppe & Desert	Black	Large	Pore	1.7	-	Soil
Cataglyphis cf. *nodus*.	Scavenger	Steppe & Desert	Black & Red	Medium	Flat	0.5	0.95± 0.05	Soil
Cataglyphis cf. *lividus*.	Scavenger	Steppe & Desert	Orange	Small	Pore	0.2	-	Soil
Formica cf. *epinotalis*	General forager	Unknown	Brown	Small	Pore	0.1	-	Soil

Fig 2. Mounds of (a) active and (b) abandoned *Messor* cf. *intermedius* nests at Roodshoor, Saveh, Iran.

This was further illustrated when the organic matter and nutrient (N, P and K) levels throughout the soil profile were considered. Duncan's multiple range test indicated that levels of all four measures were considerably higher in active nest soil compared to control soil at all four measured depths (0-10, 10.1-20, 20-1-30 and 30.1-40 cm), while levels soil of abandoned nests were virtually the same as in control soil (Fig 3). Furthermore, active ant nests had the effect of homogenizing the nutrient distribution throughout the profile, even though concentrations declined with depth in control area soils. Soil nutrient levels and profiles had regressed to control area levels in abandoned nests (Fig 3).

Unlike the control areas, which were dominated by plants *Stipa hohenackeriana*, *Brassica deflexa*, and *Artemisia sieberi,* the active nest areas were dominated by *Campanula stricta*, *Lepidium vesicarium*, *Achillea tenuifolia*, *Brassica deflexa*, *Papaver tenuifolium* and *Scabiosa oliveri* (Table 3), the major part of which were concentrated in 1m wide rings

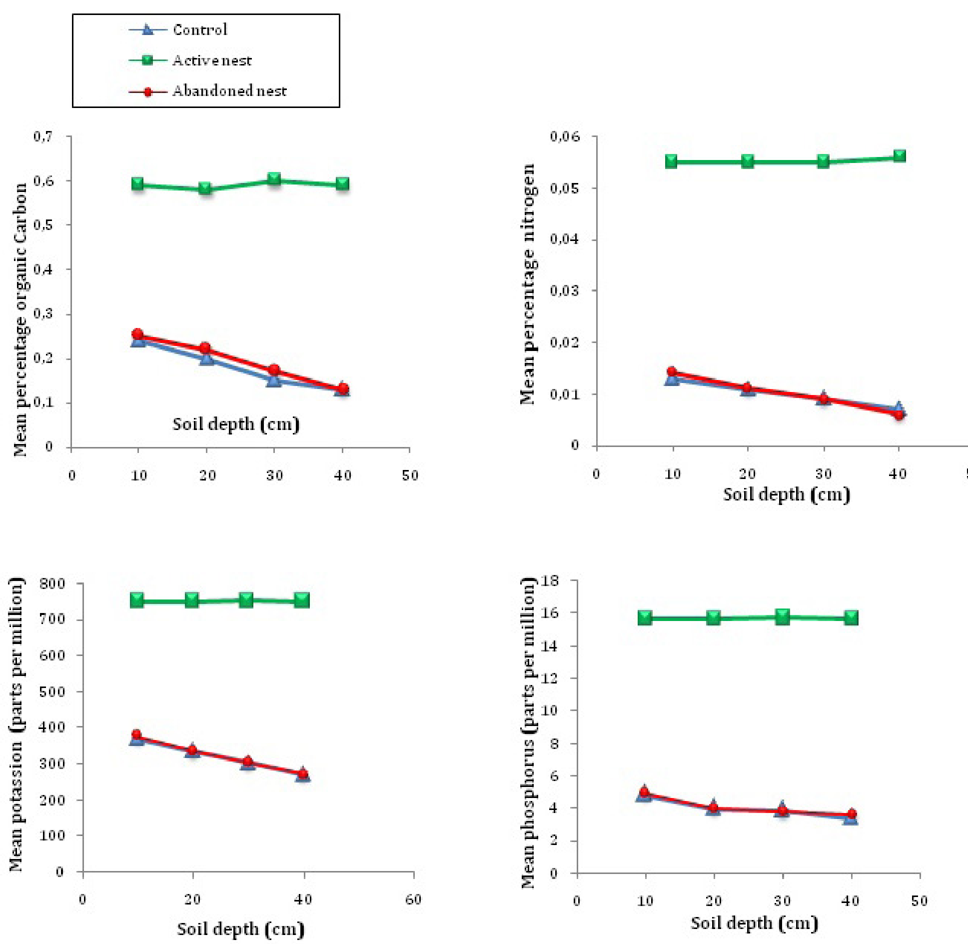

Fig 3. Nutrient concentrations of soil at four depths in active (n = 18) and abandoned (n = 7) *Messor* cf. *intermedius* mounds and control areas (n = 18).

Table 2. Line 1-16: Physical and chemical properties of soils (Mean from 0 to 40 cm) from *Messor* cf. *intermedius* mounds, dead mounds and control sites in the Roodshoor and significance of the comparison between sites by Duncan's multiple range test (Mean±S.E; control and live nest each N=18, abandoned nest N= 7). Line 17-18: Results of soil infiltration measuring under conditions of high and low soil moisture contents by double rings method (t-test, Mean±S.E; control and colony each N=5).

Properties	Mound	Control site	Abandoned mound
pH	7.47 ± 0.01^{b*}	8.30 ± 0.03^{a}	8.40 ± 0.04^{a}
Ec	3.05 ± 0.03^{a}	1.43 ± 0.06^{b}	1.30 ± 0.06^{b}
% OC	0.59 ± 0.04^{a}	0.18 ± 0.03^{b}	0.19 ± 0.02^{b}
% OM	1.13 ± 0.08^{a}	0.33 ± 0.05	^{b} 0.35 ± 0.06^{b}
%N	0.05 ± 0.005^{a}	0.01 ± 0.03^{b}	0.01 ± 0.003^{b}
P (ppm)	15.70 ± 0.7^{a}	4.01 ± 0.03^{b}	4.08 ± 0.1^{b}
K (ppm)	551.90 ± 3.8^{a}	320.10 ± 1.02^{b}	322.50 ± 7.81^{b}
Mg (mg g^{-1})	110.50 ± 0.2^{a}	90.20 ± 0.25^{b}	91.30 ± 0.01^{b}
Ca (mg g^{-1})	78.20 ± 0.1^{a}	60.40 ± 0.01^{b}	61.20 ± 0.03^{b}
% Sand	80.53 ± 0.19^{a}	77.93 ± 0.18^{b}	78.00 ± 0.15 b
% Silt	8.4 0± 0.16^{a}	8.90 ± 0.2^{a}	8.93 ± 0.2 a
% Clay	11.06 ± 0.2^{b}	13.13 ± 0.25^{a}	13.00 ± 0.21 a
Temperate - Dry season	32.00± 0.1^{a}	28.10 ± 0.01^{b}	27.50 ± 0.1 b
Temperate - Humid season	25.20 ± 0.01^{a}	22.00 ± 0.2^{b}	23.40 ± 0.003 b
Moisture - Dry season	6.50 ± 0.6^{a}	4.20 ± 0.01^{b}	4.90 ± 0.02 b
Moisture - Humid season	9.30 ± 0.3^{a}	7.40 ± 0.05^{b}	7.80 ± 0.001 b
Infiltration rate - Dry season (mm)	34.74 ± 1.30^{a}	21.66 ± 0.56^{b}	**
Infiltration rate - Humid season (mm)	40.32 ± 1.88^{a}	22.94 ± 0.65^{b}	**

* The means of the rows with same letters were shown not significantly different by Duncan's multiple range test

** Not measured

around the periphery of the nest, which itself was largely devoid of plant cover (Fig 2). When these surrounding rings were included for comparison with control areas, the active nests had significantly higher vegetation cover, plant species richness and diversity, lower grass cover, higher forb cover and an absence of shrubs. The situation changed markedly on abandoned nests, which were totally dominated by the forb *Campanula stricta*, leading to significantly higher vegetation cover but lower plant species richness, diversity and evenness than on active nests (Table 3). Furthermore, the vegetation on abandoned nests was more evenly distributed, with no vegetated ring or bare centre being evident (Fig 2).

Discussion

These observations on the influence of *Messor* ants add to those from southern Europe (e.g., Cammeraat et al., 2002), Africa (e.g., Dean & Yeaton, 1993) and parts of Western Asia (e.g. Ginzberg et al., 2008; Brown et al., 2012), the other regions of the world where this genus of seed harvester ants is found.

As in these other studies, the Iranian *Messor* nests have a profound influence on soil chemistry, although this effect diminishes once the nests are abandoned and the ants cease their harvesting and soil-moving activities. The time taken for this effect to diminish was not measured. Considering the nest diameter and density of *Messor* cf. *intermedius* nests, the area

Table 3. Above: Mean importance value index (IVI) for plants species and mean (± SE) percentage cover of different functional groups of plants. Below: Plant species richness (S), diversity (H'), and evenness (E) for active and abandoned *Messor* cf. *intermedius* nests and control sites (Mean ± SE).

Family	Species name	IVI		
		Control	Active nest	Abandoned nest
Campanulaceae*	*Campanula stricta*	1.03	<u>18.78</u>	<u>45.03</u>
	Silene chaetodonta	1.11	1.1	-
Chenopodiaceae	*Salsola laricina*	2.07	-	-
	Salsola tomentosa	2.54	-	-
Compositae	*Achillea tenuifolia*	1.47	<u>7.11</u>	1.13
	Anthemis gilanica	2.35	3.56	1.07
	Artemisia sieberi	<u>5.54</u>	-	-
	Centaurea behen	3.84	3.01	-
	Centaurea bruguierana	1.04	1.21	-
	Cousinia belangeri	1.07	1.25	-
	Echinops pungens	1.18	1.05	-

Table 3. Above: Mean importance value index (IVI) for plants species and mean (± SE) percentage cover of different functional groups of plants. Below: Plant species richness (S), diversity (H'), and evenness (E) for active and abandoned *Messor* cf. *intermedius* nests and control sites (Mean ± SE). (Continuation)

Family	Species name	IVI		
		Control	Active nest	Abandoned nest
Compositae	*Senecio vernalis*	1.06	1.12	-
	Taraxacum vulgare complex	1.32	1.61	-
Cruciferae	*Alyssum marginatum*	2.11	3.17	-
	Brassica deflexa	<u>7.07</u>	<u>7</u>	1.03
	Lepidium vesicarium	1.21	<u>15.07</u>	-
	Sisymbrium officinale	1.05	1.06	-
Gramineae	*Stipa hohenackeriana*	<u>9.14</u>	1.12	-
	Aegilops columnaris	1.07	1.17	-
	Anisantha tectorum	1.21	2.09	-
	Hordeum murinum	2.11	1.2	-
	Poa sinaica	2.15	1.07	-
Ephedraceae	*Ephedra strobilacea*	2.15	-	-
Euphorbiaceae	*Euphorbia sororia*	1.14	2.02	-
Dipsacaceae	*Scabiosa oliveri*	1.1	<u>5.89</u>	1.03
Geraniaceae	*Erodium oxyrrhynchum*	2.2	3.4	-
Labiatae	*Ziziphora tenuior*	1.62	2.73	-
Papaveraceae	*Papaver tenuifolium*	1.09	<u>6.07</u>	1.05
Fabaceae	*Astragalus chaborasicus*	2.08	1.1	-
Apiaceae	*Ferula hirtella*	2.12	1.11	-
Valerianaceae	*Valerianella oxyrrhyncha*	1.02	1.04	-
Percentage plant cover **	Grass	14.83 ± 2.30 ^{a}	4.44 ± 0.01 ^{b}	-
	Forb	21.83 ± 0.42 ^{c}	62.94 ± 0.94 ^{b}	82.57 ± 1.30 ^{a}
	Shrub	9.22 ± 0.01	-	-
Indices **	Vegetation Cover (%)	45.88 ^{c}	67.88 ^{b}	82.57^{a}
	Richness (S)	6.44 ^{b}	12.33 ^{a}	2.85 ^{c}
	Diversity (H')	1.73 ^{b}	2.26 ^{a}	0.39 ^{c}
	Evenness (E)	0.40 ^{a}	0.45 ^{a}	0.13 ^{b}

* The underlined data has higher values of IVI for treatments
** The means of the rows with same letters were shown not significantly different by Duncan's multiple range test.

under the influence of active nests represents less than 1% of the total area, even if the additional but unmeasured influence of *Messor* cf. *subgracilinodis* is included. However, the implications to biodiversity are profound. The active nests, and to a lesser extent, the abandoned nests, produce changes in the dominance of the vegetation and, as a result, increase the heterogeneity or patchiness of the environment. This is likely to enhance the diversity of invertebrate (Siemann, 1998), and possibly vertebrate animals (Murkin & Batt, 1987) that directly or indirectly depend on the plant species and vegetation structure of the region or the invertebrates on which they may feed.

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Authors contribution

Mahsa Ghobardi conducted this work for a higher degree thesis under the supervision of Donat Agosti, Mohammad Mahdaviand Mohammad Hassan Jouri. Jonathan Majer assisted with the preparation of this review of the work. All data have been cleared for copyright with the journal in which the primary papers were published.