سی و چهارمین گردهمایی
و دومین کنگره بین المللی تخصصی علوم زمین

2016

The 34th National & the 2nd International Geosciences Congress

CERTIFICATE

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This is to certify that your paper entitled "**Pedogeomorphic characteristics and resilience variability in arid landscape**"

has been accepted as poster in the 34th National & the 2nd International Geosciences Congress which was held in the Geological Survey of Iran, 22- 24 February 2016.

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Pedogeomorphic characteristics and resilience variability in arid landscape

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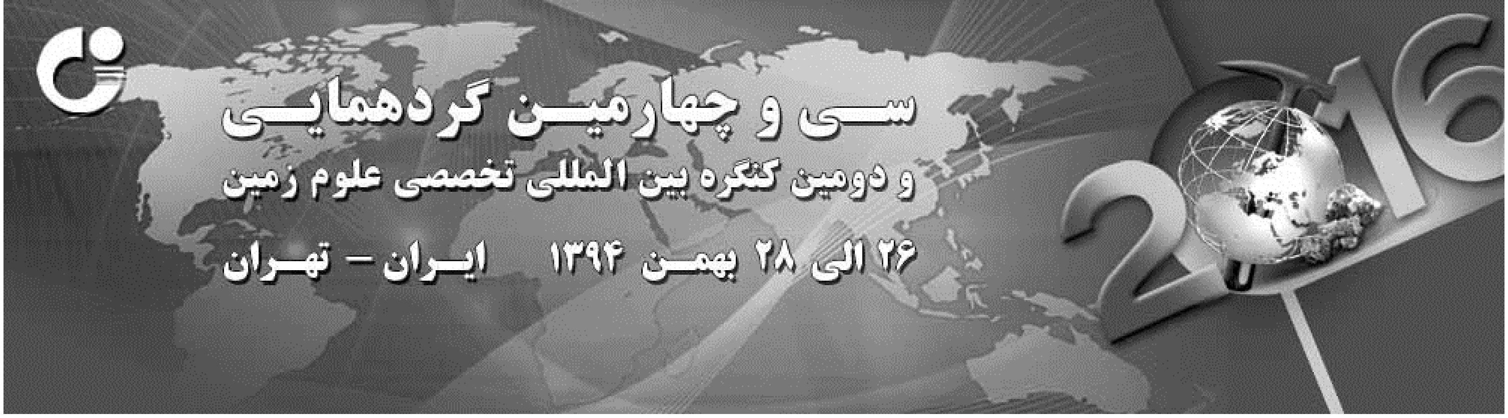
Abstract

Since soil is the context of the formation and landscape evolution, any changes in it’s physical, chemical, and biological attributes may push ecosystem toward degraded conditions. Furthermore the concept of sustainable ecosystems management can directly be related to the sustainable soil management. Variations of biotic-abiotic soil attributes affect arid landscape resilience to environmental disturbances. In this regard assessment of changes of physical, chemical, and biological soil indicators can be a useful tool for understanding the landscape dynamic trends especially desertification process in arid ecosystems. The aim of this paper is an overview of application of biotic-abiotic soil indicators monitoring in the arid ecosystems management against hazards risk. The results of this paper suggested that biotic-abiotic soil indicators monitoring including variations in vegetation organizations and soil physiochemical properties can provide an new opportunity for decision makers for advancing sustainable landscapes management especially on the resource-limited ecosystems.

Keywords : Biotic-abiotic soil indicators. Landscape evolution. Resilience. Sustainable management.



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Abstract

Since soil is the context of the formation and landscape evolution, any changes in it's physical, chemical, and biological attributes may push ecosystem toward degraded conditions. Furthermore the concept of sustainable ecosystems management can directly be related to the sustainable soil management. Variations of biotic-abiotic soil attributes affect arid landscape resilience to environmental disturbances. In this regard assessment of changes of physical, chemical, and biological soil indicators can be a useful tool for understanding the landscape dynamic trends especially desertification process in arid ecosystems. The aim of this paper is an overview of application of biotic-abiotic soil indicators monitoring in the arid ecosystems management against hazards risk. The results of this paper suggested that biotic-abiotic soil indicators monitoring including variations in vegetation organizations and soil physiochemical properties can provide an new opportunity for decision makers for advancing sustainable landscapes management especially on the resource-limited ecosystems.

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Introduction

Environmental changes can occur in a gradual, continuous way or exhibit sudden discontinuities. When external changes are gradual, some ecosystems may respond in a smooth, gradual manner, whereas others may remain inert until a threshold in external conditions is passed, at which point the system suddenly switches from one state to another. These sudden or catastrophic shifts are often accompanied by degradation of ecosystem services and concomitant economic losses. Arid ecosystems are an example of fragile ecosystems to losses of vegetation and soil services that abruptly switch to desert state because of climatic variations or human activities (Scheffer et al., 2001; Reynolds & Smith 2002; Foley et al., 2003). Catastrophic shifts lead to emergence of alternative stable states, meaning that, for certain external conditions, the system exhibit more than one stable state. One of the most useful applications of the alternative stable states theory in geomorphic systems is to predict the potential of an ecosystem to switch to degraded state (such as desert state). Catastrophic shifts between alternative stable states generate by positive feedbacks (Scheffer et al., 2001; Rietkerk et al., 2004). Positive feedbacks occur when an organism amplifies disturbances or environmental processes, driving the system away from equilibrium. Furthermore, positive feedbacks are a cause of emergence of alternative stable states in community composition such as vegetation biomass within systems. But how can we predict the emergence of positive feedbacks-induced alternative stable states?

Soil as the context of the formation and landscapes evolution is a important component of the earth's biosphere, functioning not only in the production of human's needs but also in the maintenance of local, regional, and global environmental quality (Doran & Zeiss 2000). So that losses of soil biodiversity can be result in non-equilibrated landscapes state. In this regard physical, chemical, and biological properties of soil are critical criteria for assessing soil quality and health degree to hazards risk. Accordingly measurements of biotic and abiotic soil factors can be a useful tool for sustainable land management. Although soils have been widely studied and classified in terms of physical and chemical characteristics, but knowledge of soil biodiversity and function also their relationship with landscape evolution is far from complete. In recent years many researchers have tried assess soil quality meaning that, "the ability of soils to deliver ecosystem services in a sustainable way" (Doran & Zeiss 2000; Peres et al., 2011) as well as soil variations rate in presence of different processes with aim of predicting landscape response to induced-disturbances by using different indicators.

Understanding the interactions between internal soil variables (abiotic soil indicators such as physiochemical properties) and external soil variables (biotic soil indicators such as vegetation) also variations them over time can be an influential agents for monitoring stability or non-stability of landscapes state. In this regard in the present paper have been demonstrated that how abiotic (physiochemical attributes) and biotic (vegetation organization) soil indicators can be a key for aridlands degradation trends monitoring also an early warning alarms for emergence of multiple stable states in response to disturbances. The results of this research can be a new conceptual approach for managing the hazards in arid and semi-arid landscapes.

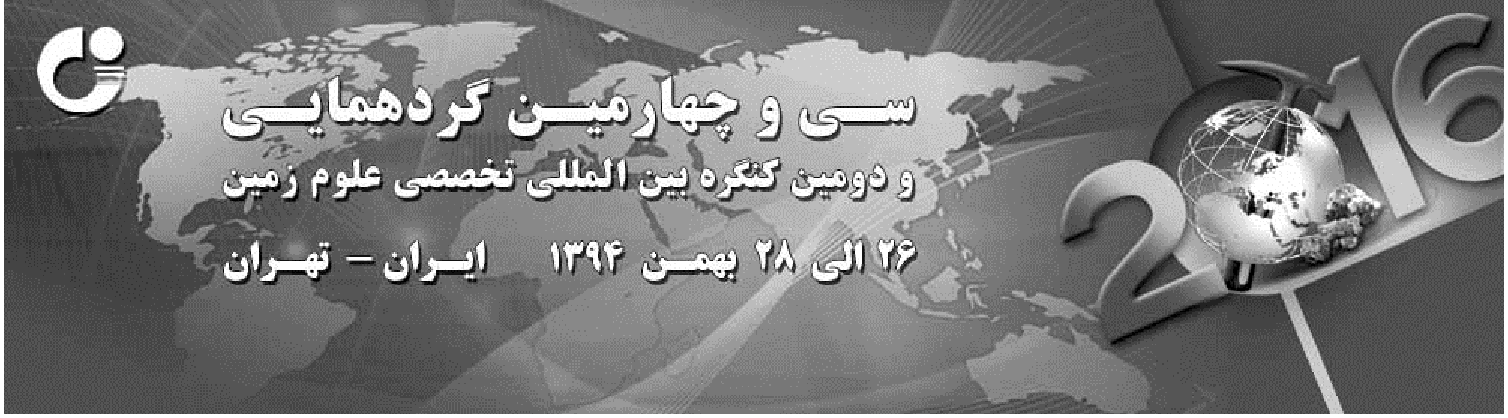
Methods and Discussion

Linkages within the biotic-abiotic soil indicators

The concept of indicator is widely used in environmental monitoring in relation to natural and anthropogenic hazards. Such indicators, either biological, physical, or chemical, give information about the landscape current state and evolution trends it over time. As defined in this paper, the biotic-abiotic soil indicators are the external soil variables such as vegetation composition and internal soil variables such as physiochemical properties (e.g., soil texture, structure, EC and pH level). These indicators provide a background for environmental states monitoring in response to a wide range of disturbances (Peres et al., 2011).

Biotic soil indicators as fast variables are factors that quickly respond to disturbances and most easily measured by managers. These indicators including characteristics of plants and their organization in terms of presence/absence, morphology, physiology and, geometry are direct alarms for examination of soil quality, extent of abiotic soils indicators shifts, and their degradation trends. Monitoring them give information on the ecosystem current and future state. Biotic soil indicators (plant) affect soil quality. These indicators plays a key role in determining the physical and chemical soil properties as well as productivity it. Decreasing vegetation cover and expansion of bare ground with the occurrence of a hydrophobic layer can increase erosion rates (Wainwright et al., 2000; Gabet & Sternberg 2008). On the other hand the vegetation contributes organic carbon to soil. These carbon transfers influence the level of atmospheric carbon dioxide that, in turn, affects climate (Schlesinger 2002; Berner 2004). Increasing vegetation cover result in increasing soil infiltration capacity which, in turn, provide a background for plants stability. Furthermore enlargement of vegetation can be an inhibitor for soil degradation, maintaining biodiversity it and subsequent landscape equilibrium against hazards.

Abiotic soil indicators based on physical and chemical parameters of soil (Morvan et al., 2006; Kibblewhite et al., 2008) are slow variables that change slowly in response to long-term processes and hazards also constrain responses of fast variables. In this regard slow variables are indirect indicators for assessment of ecosystem resilience. Abiotic soil indicators provide a context for stability or non-stability of vegetation in term of plant-available water and other resources. Plant-available water and subsequent vegetation establishment is affected by the capability of soil to absorb, store, and release water to plants that depending to physiochemical soil properties. For example, the available water holding capacity of silt loam textures is greater than coarse sands or $CaCO_3$ is an inhibitor factor for plant stability that increasing its' accumulation leads to soil impermeability.



Thus, physical and chemical soil properties such as pH, salinity, $CaCO_3$ also particles size distribution, exert important controls on vegetation in arid and semi-arid ecosystems.

Spatial scale of biotic-abiotic soil indicators and landscape evolution

The size of the biotic-abiotic soil indicators variations is a critical criterion for landscape current state monitoring and forecasting it's future state. The occurrence of diffuse heterogeneities in biotic and abiotic soil properties can be an early warning alarms for decreasing landscape resilience and gradual event of non-equilibrium transitions toward degraded conditions. For example the emergence of heterogeneities in distributions of patchy structures (vegetated area within barren ground) also heterogeneities within landscape dominant soil such as variations in $CaCO_3$,EC, particles size distribution, pH and etc.
Dominant processes in drylands are effective agents on the emergence of local heterogeneities in biotic and abiotic soil indicators. Wind is a major factor of detachment and transport of fine soil particles from bare grounds and their deposition on the vegetated patches. This process with changing surface soil texture and occurrence of local soil heterogeneities leads to emergence of geomorphic differences such as contrast in soil infiltration capacity and consequently modification of vegetation structures (Ravi et al., 2010). Also impacts of land subsidence as a widespread hazard in arid ecosystems on the occurrence of heterogeneities in biotic and abiotic soil indicators (case study: an arid ecotone at Khorasan-e Razavi). The results of laboratory-experimental observations showed that earth fissures related to land subsidence with changing biotic and abiotic soil indicators (e.g., EC, $CaCO_3$, clay percentage, variations in density ratio of vegetation) and subsequent occurrence of fine scale soil heterogeneities exhibit invisible boundaries between different locations of ecotone along with asymmetric distribution of patchy structures. The condition that has caused the emergence of multiple stable state across landscape (Fig. 1).

Changes of coupled biotic-abiotic soil indicators occur at long-term time-scales, as with Quaternary landscape evolution, and at short-term time-scales, as with the desertification event that has been taking place in the arid ecosystems such as Khorasan-e Razavi. Increasing grazing level, changes of land use especially increasing agriculture lands and over-exploitation of groundwater which occur land subsidence, have been caused vegetation destruction, soil compaction and ultimately development of bare grounds. Reduced ground cover led to more bare soil and consequently to increased erosion. Increasing erosional processes create a context for emergence of variations in biotic and abiotic properties of soil. All these variations encourage emergence of alternative stable states as vegetated and barren patches that can be an alarm for probability event of desertification over time. As a result monitoring heterogeneities occurred on the biotic-abiotic soil indicators (due to impacts of environmental disturbances) can provide an good opportunity for forecasting transition trends of ecosystem toward degraded states.
Yet, not all biotic-abiotic soil indicators are equally prone to change. Resistance of some vegetated patches in the arid ecosystems of Khorasan-e Razavi to desertification suggested that formation of diffuse heterogeneities within landscape dominant soil (e.g., variations in EC, CaCO3, pH level) result in the occurrence of differences in vulnerability of the soils to compaction due to processes such as land subsidence or wind erosion in arid ecosystems. Furthermore the occurrence of fine-scale heterogeneities in the biotic-abiotic soil indicators provide a context for the emergence of multiple stable states across landscape. These variations monitoring can be a tool for predicting landscape collapse possibility. The emergence of such variations under disturbance condition create an opportunity for more stability of plant and subsequent promote landscape resilience against disturbances due to niche differences (Williams & Houseman 2013).

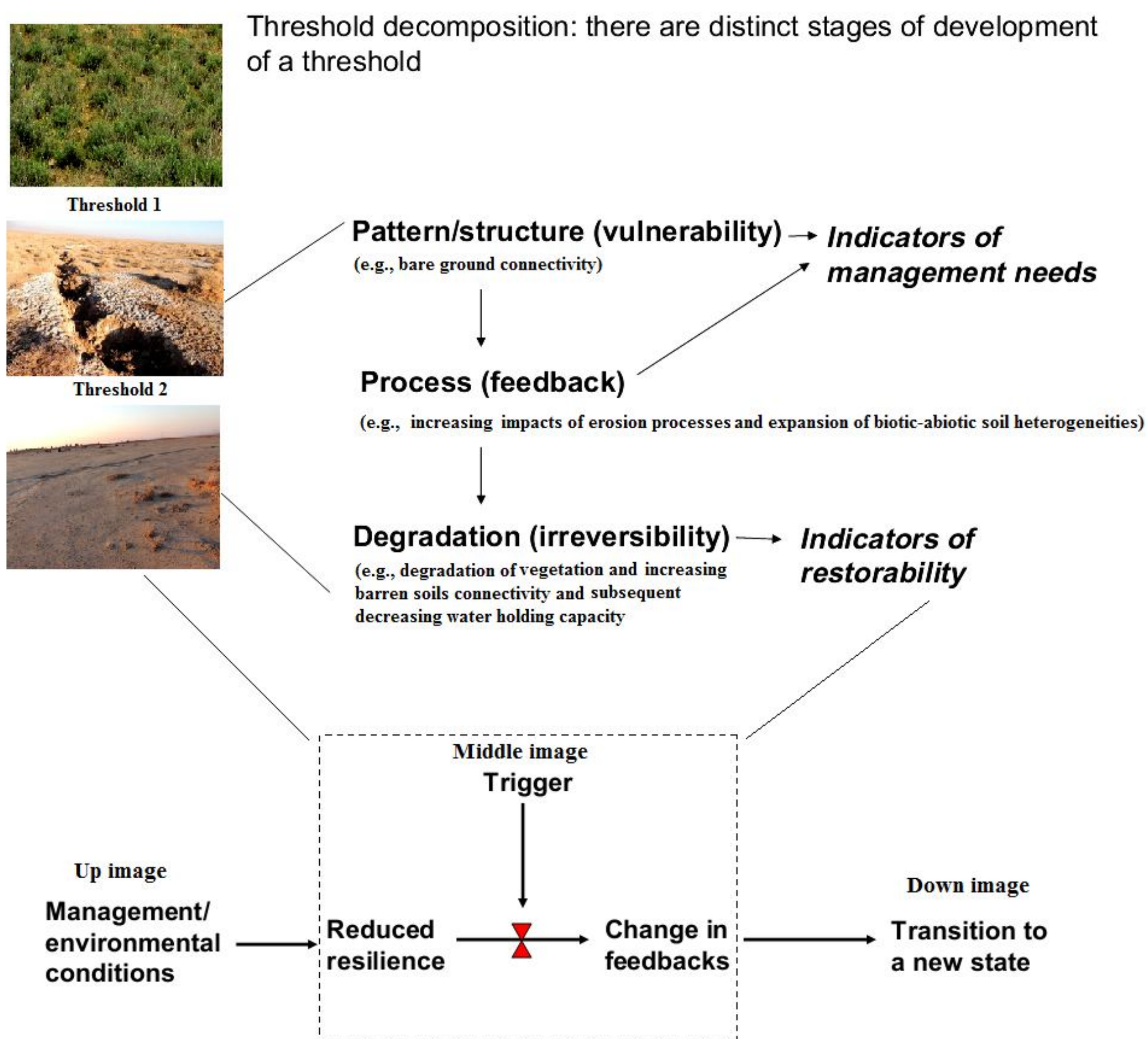
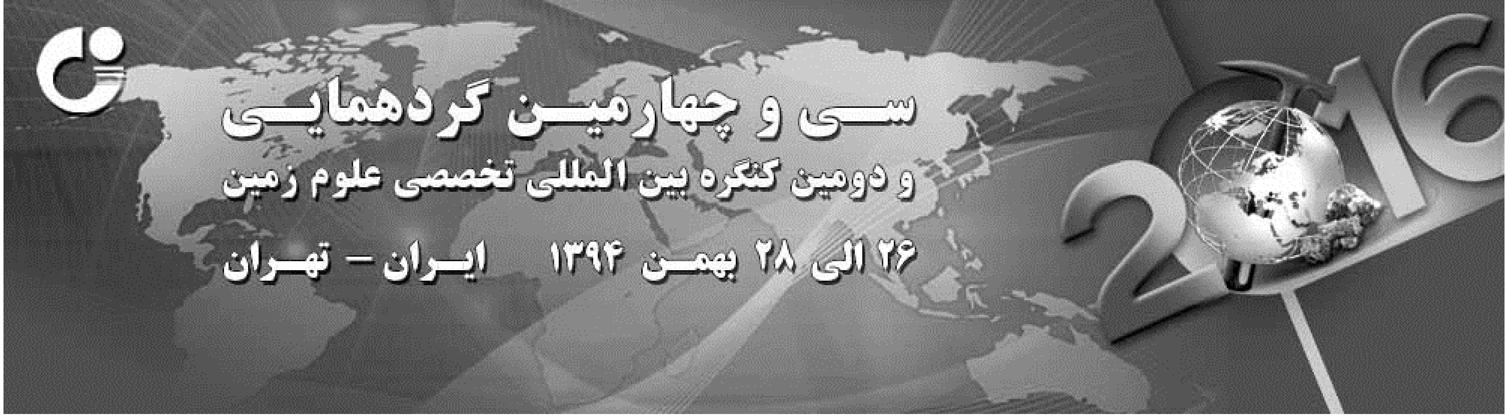


Fig 1. Indicators for identification and forecasting landscape evolution trends: up image) threshold initiation, middle image) change of feedbacks, and down image) persistent degradation. Up to down: Variations in vegetation patches structure (biotic soil indicator) due to variations in physiochemical soil properties (abiotic soil indicator) and subsequent transition between alternative stable states from uniform vegetated area toward uniform barren ground (based on findings a case study at Khorasan-e Razavi).



Conclusion

Soil formation is a slow process, while physical, chemical, and biological degradation processes of soil, such as soil compaction, erosion, acidification, etc., can occur relatively fast in reaction to environmental disturbances. In this regard biotic-abiotic soil indicators monitoring can be a suitable tool for forecasting and subsequent managing changes trends of landscape. Differences in vulnerability of the soils to erosional processes such as land subsidence-induced soil compaction result in the emergence of diffuse heterogeneities in the soil attributes along with different distributions of patchy structures (vegetated area and barren patches). Consequence of such variations is occurrence of alternative stable states as dense vegetated areas and diffuse barren patches across landscape. Furthermore bare soils connectivity over time can be an qualitative indicator for measurement of arid landscapes resilience. Such conditions can be an early-warning signal for management needs. A greater understanding the interactions among biotic and abiotic soil indicators with environmental disturbances can help us explain and manage the variability inherent to arid and semi-arid ecosystems.

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