Volcanic impacts on grasslands – a review

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Abstract

Volcanic eruptions have a wide range of effects on many of the Earth's grassland systems, such as in Africa, the Americas and Iceland. The effects are determined by the severity of the impact, vegetation height and the resilience of the impacted system. Biological soil crusts, often an important component of dryland grazing systems, are severely affected by thin deposition of volcanic ash, whereas taller vegetation with ample nutrient supplies is more tolerant to such disturbances. Redistribution of airborne unconsolidated volcanic materials (tephra, including volcanic ash) in the aftermath of eruptions is often quite harmful to ecosystem survival. The interaction between volcanic events and land-use practices such as grazing is detrimental. Alien plant species in volcanic areas can severely interfere with ecosystem recovery.

Keywords: tephra, volcanic ash, volcanic impact, grazing

Introduction

There are 1545 active volcanoes with >9000 eruptions listed in the current *Smithsonian Catalog of Active Volcanoes* (Siebert *et al*., 2010). About 70 volcanoes are active each year on average, but most eruptions are small. The majority of volcanoes occur at the margins of tectonic plates, which account for 94% of the volcanic activity, with the 'Pacific Ring of Fire' and the African Rift Valley being good examples (Simkin and Siebert, 2000). The activity occurs also in relation to so-called hot spots, which are isolated and transfer heat from the mantle (Bjarnason, 2008), such as on the islands of Hawaii, Galapagos and Iceland, and in Yellowstone, which is an example of intra-continental volcanic hot-spot activity. The volcanic activity affects most of the world's ecosystems as airborne volcanic materials are dispersed over large areas. The impacts vary considerably because of the different nature of volcanic eruptions and the ecosystems being affected. In this paper, the nature of these impacts will be investigated based on published literature with emphasis on grassland ecosystems and volcanic tephra (ash). Over 500 articles were reviewed, but only a few are mentioned here due to space constraints. The full review will be published in Advances in Agronomy (Arnalds, 2013).

Nature of the volcanic ejecta

The most common types of impacts are related to outputs of lavas and airborne volcanic materials. The term for airborne volcanic ejecta is 'tephra', but 'ash' is defined as tephra <2 mm in diameter. Other outputs that can have pronounced effects on ecosystems are: i) pyroclastic flows, which have devastating influences on the affected areas; ii) lahars, which are a mixture of solid volcanic materials and water that also are very destructive, and iii) jökulhlaups which are flood events that result from melting ice during eruptions (see chapters in Sigurdsson *et al*., 2000). The effects of volcanic tephra are dependent on the amount of the tephra, which is commonly reported by the depth of deposition. However, grain size and chemical composition, ranging from basaltic to silicious tephra, also influence ecosystem impacts. The basaltic tephra is more easily weathered, releasing available cations that improve ecosystem fertility, whereas the silicious tephra weathers more slowly and can result in acidic soils. Tephra that falls on snow can, to an extent, be removed by snowmelt, thus decreasing volcanic impacts.

Responses of plants to tephra burial

The ability of vegetation to recover after tephra deposition is in part determined by the height and physiology of the vegetation. Buried plants are deprived of sunlight, and regrowth depends on reserves, with increased elongation of apical meristem, upward growth of apices, rhizomes and shoots (Maun, 1998). Plants that succeed have a chance to utilize reserves otherwise not available to them (Gilbert and Ripley, 2008). The plants vary in their response: some die, some are little affected, while others may show positive responses (Maun, 1988), and this difference results in changes in botanical composition upon impacts. The low-growing lichens, mosses and biological soil crusts are extremely vulnerable to disturbance, as is seen in Iceland (Aradottir *et al.*, 2010). Many of the grassland species can tolerate tephra deposition of similar depth to the vegetation height. Thin deposition (<1-2 cm) on low-growing dryland vegetation, especially crust-dominated systems, can be detrimental. Recovery rates for grasslands under relatively dry climatic conditions can be expected to reach decades where burial exceeds the vegetation height (as judged from a review of the literature). Subtle volcanic inputs (<1 mm) can, however, be quite beneficial by recharging soils with plant-available nutrients, influencing areas at great distances from the origin of the tephra.

Tephra redistribution

Volcanic tephra affects the physical properties of the surface, such as infiltration rates and run-off, and this depends much on the nature of tephra. Reduced infiltration rates, with increased run-off, are more often reported than enhanced rates. Redistribution of tephra to depths exceeding the vegetation height can be enormous, both by wind and water. While redistribution of tephra can reduce the tephra depth, it can cause severe damage as well. Water erosion can reach staggering proportions of >100,000 t km^{-2} yr^{-1} (e.g., Pinatubo, Philippines; Eyjafjallajökull, Iceland), with deflation rates exceeding 10 mm yr^{-1}. Wind distribution can also be severe with negative effects such as reoccurring dust pollution long after initial tephra inputs, as witnessed after the 1991 Hudson eruption (Chile; Wilson *et al.*, 2011) and the 2010 Eyjafjallajökull eruption (Iceland).

Volcanic eruptions, grazing and ecosystem resilience

Recovery of grasslands after severe volcanic disturbances is dependent on the ability of the vegetation to stabilize the tephra, which depends not only on vegetation height and composition, but also on the available nutrient reserves. Systems with tall-growing species and ample nutrient reserves provide resilience against eruptions. Grazing affects vegetation height, which can be quite low in degraded systems. This is exemplified by the communal grazing lands in Iceland where grazing is a detrimental factor for survival after volcanic impacts. Low-growing vegetation facilitates redistribution of the tephra, often with harmful effects on neighbouring ecosystems. Wind transport of tephra from bare erosion spots also leads to enhanced tephra thickness elsewhere. Dryland grassland systems, where biological soil crusts are important ecosystem components, suffer severely from volcanic disturbances, as is witnessed after the 2010 Eyjafjallajökull eruption in Iceland. It can be concluded that the ability of Icelandic ecosystems to recover from volcanic impacts has been greatly reduced over the >1100 years since Iceland was settled.

Exotic/alien species

Land use and the introduction of new species may influence recovery of grassland ecosystems after tephra deposition. Many such plants are invasive in nature and their spread may become facilitated after eruptions, which has compounded ecosystem recovery in many volcanic areas. It is clear that the use of exotic invasive species should be avoided in volcanic areas unless their effects on recovery and ecosystem development after eruptions are fully understood.

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