THE SOILS OF ICELAND – abstracts

Chapter 1. Introduction

This book about the soils of Iceland takes a broad approach considering soils as a part of the environment and ecosystems resulting in a publication giving a wide-ranging insight into Icelandic nature in general. It gives a short overview of Icelandic climate and land use with special consideration to the volcanic geology, which is the single most important factor in determining soil formation on this island: the formation of Andosols. The book describes a simple classification scheme for soils of Iceland, where Vitrisols, soils of the extensive Icelandic deserts (Andisols under ST), are a prominent part of the system. Physical and chemical properties of the soils are discussed in separate chapters, as is pedogenesis, with numerous photos, figures, descriptions, and tabular data. Geomorphic processes are especially active in Iceland and separate chapters are therefore devoted to the effects of frost on soils and the environment, and on aeolian processes, which are extremely active, influencing the main properties of all soils in Iceland. In no other country outside of the arid regions has land degradation and soil erosion had as detrimental consequences as in Iceland, which is addressed in the final chapter of the book.

Chapter 2. High in the North – Climate, People and Agriculture

The chapter presents background information about the climate, people and agriculture in Iceland, together with some historical notes. The climate of Iceland reflects the northerly location in the North-Atlantic Ocean, with windy, moist climate, relatively mild winters but cool summers. Winter temperatures often linger about 0 °C in the lowlands. Iceland was settled in the 8th and 9th Centuries, with a rapid population increase. Harsh climate and degrading natural resources were a major challenge for survival in Iceland with the population remaining below 60,000 most of medieval times. Icelanders are now about 320,000. There are about 2,600 active farms with about 75,000 cattle, 460,000 sheep and 80,000 horses. The sheep and cattle depend on hay making in summer, but the animals are kept indoors in winter. Importance of forestry, both as restoration activity and as an industry, is growing.

Chapter 3. Geology

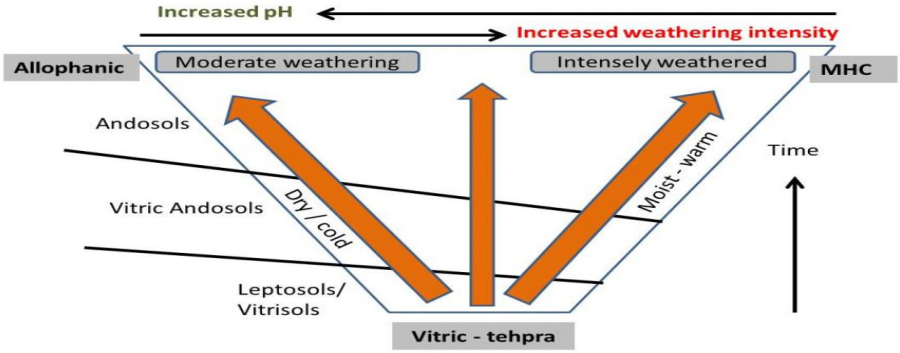
Iceland is a volcanic island on the Mid-Atlantic Ridge with about 30 active volcanic systems and eruptions every 3-5 yrs, fed by a volcanic mantle plume under the island resulting in a so-called hotspot. The oldest rocks are from the late Tertiary, but much of the surface is covered by rocks < 3 million yrs old, with widespread Holocene lava and tephra deposits. Glaciers cover about 11% of the country and many active volcanoes are located under ice. The volcanism provides the parent materials of Icelandic soils by tephra deposition and aeolian redistribution. These materials are primarily basaltic in composition, while andesite and rhyolite also occur. The use of dated tephra-layers in the soil is an important tool in environmental and archeological sciences in Iceland. The Quaternary glacier has carved out deep valleys in the Tertiary rock formations, while more recent landscapes are often characterized by plains and with mountains associated with volcanic systems. Glacial rivers and glacial margins are major sources for the aeolian materials mantling Icelandic land surfaces. Volcanic centers active during the Tertiary are often prominent on the landscapes, carved out by the Quaternary glaciation. Iceland receives large amount of precipitation leading to many streams and major rivers, which include spring-fed rivers, glacial rivers and runoff based rivers.

Chapter 4. Vegetation and Ecosystems

The chapter presents the results of the Agricultural University of Iceland vegetation classification, which is based on separating the vegetation into 10 classes. Iceland has the poorest vegetation cover of all countries in Europe, less than 45%. Heathlands, especially poor heathland (25,000 km^2), is the most abundant vegetation, wetlands comprise about 8000 km^2 but deserts of various kind >40,000 km^2. The heathlands reflect the long-lasting grazing of these systems. The wetlands are in many ways unique blend of aquic, Arctic and andic soil systems and are especially important ecosystems. Most of the lowland wetlands have been drained for agricultural purposes. Biological soil crusts are essential component of many of Icelandic ecosystems. Icelandic deserts are the largest volcaniclastic deserts on Earth. These soil surfaces are variable but many desert soils dry out easily in spite of ample rainfall in many parts. The deserts shed a new light on such terms as a ‘desert’ and ‘desertification’. Introduced invasive species are of concern for Icelandic nature.

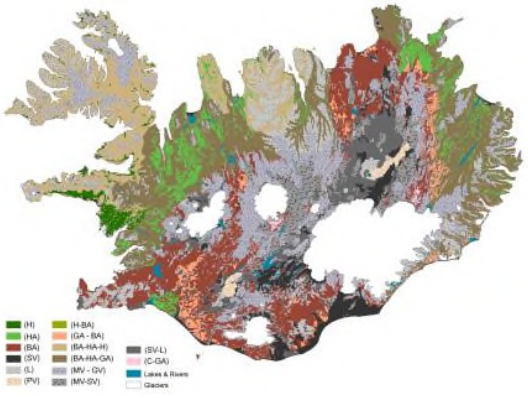
Chapter 5. Andosols – Soils of Volcanic Regions

Almost all soils of Iceland are Andosols and therefore the general properties of Andosols are discussed in this chapter. Andosols form in volcanic regions of Earth, and cover about 1% of Earth's surface. Andosols, including soils of Iceland, exhibit unique soil properties such as unusual carbon accumulation, deep soil profiles, lack of cohesion, high water holding capacity and rapid hydraulic conductivity, low bulk density, and high phosphorus retention. These properties are largely attributed to the colloidal components of Andosols, which rarely occur in abundance in other soils. These include: allophane, imogolite, ferrihydrite, metal-humus complexes, which are all important in soils of Iceland. An emphasis is given to the three major axis's of Andosols: allophanic, alu-andic (metal-humus complexes) and vitric, as these are important in separation of soils of Iceland. Vitric materials are poorly weathered volcanic ejecta, of varying composition, which dominate a large fraction of Icelandic soil materials. Many of the general physical and chemical properties of Andosols are discussed, but subsequent chapters will cover classification and properties of the soils in more detail.



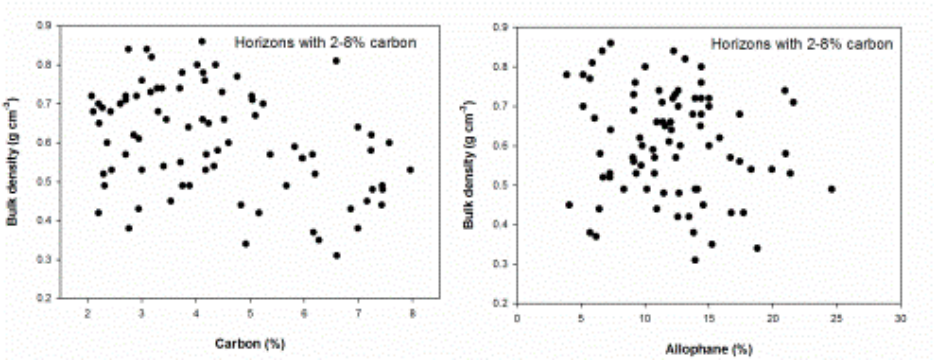
Chapter 6. Classification and the Main Soil Types

The soils of Iceland are separated based into four major categories according to the Icelandic classification scheme used in this publication: Andosols, Histosols, Vitrisols and other soils. Andosols are separated into Brown Andosols, Gleyic Andosols and Histic Andosols, based on carbon content and drainage. The Vitrisols are the soils of the barren areas and are characterized by vitric materials, low organic and allophane content and include Sandy, Cambic and Pumice Vitrisols. Aeolian sedimentation is a major factor in shaping the type of soils. Soils far from aeolian sources tend to be rich in organic matter, with Histosols in poorly drained areas and allophane rich Brown Andosols at freely drained sites. Soils close to the aeolian sources are often coarse, and wetland soils are defined as Gleyic Andosols with OC < 12%. Icelandic wetland soils are a peculiar mixture of organic and andic soils under sub-arctic conditions. Histosols (peat soils, >20 %C) are not common, in spite of extensive wetlands, and are only found far from aeolian sources. The Icelandic Andosols often have many distinct tephra layers, especially soils close to the active volcanic systems. Vitrisols, andic soils of the barren surfaces, cover more than 40% of Iceland, but their characteristics are chiefly defined by the geology and geomorphology of each area. Sandy Vitrisols are abundant, and even though the majority of the soil materials are volcanic ash with low amount of allophane or organic matter, they still qualify as Andisols (Soil Taxonomy) or Andosols (WRB) under the major international classification systems.



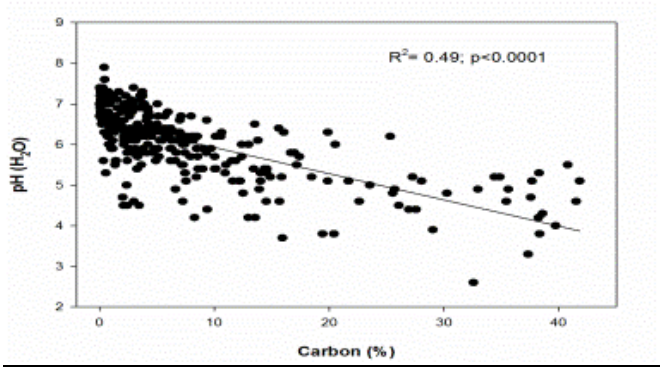
Chapter 7. Physical Characteristics

Icelandic Andosols are predominantly silt loams but coarse textured soils occur on the active volcanic zone and near aeolian sources. Numerous tephra and aeolian layers render stratification of the soils. Bulk density is low (<0.8 g cm^{-3} for Andosols) controlled by the carbon content and allophane at low carbon levels. The Vitrisols (vitric/andic soils of the deserts) are sandy and have higher bulk densities. Icelandic Andosols and Histosols have very high water retention, rapid infiltration rates, and favorable hydraulic conductivities, but coarse tephra layers have negative effects on hydraulic conductivities. Concrete ice forms under desert surfaces in winter, impeding infiltration and causing surface runoff. Lack of cohesion and thixotropic nature make the soils susceptible to water erosion and landslides, but the silt aggregation of allophanic materials makes them vulnerable to wind erosion. Pedon descriptions are provided for 9 different soils at the end of the chapter.



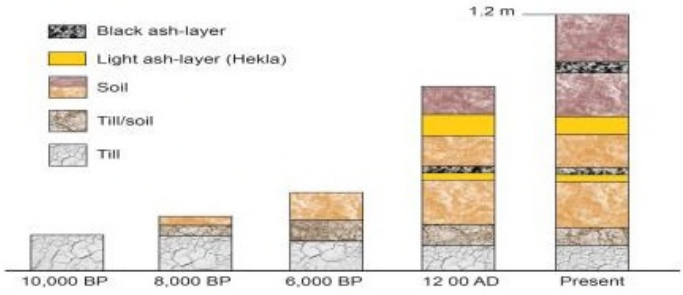
Chapter 8. Chemical Characteristics

The chapter describes chemical properties of the soils of Iceland. Soil reaction (pH) is controlled by aeolian additions of basaltic materials, which release cations upon weathering and is commonly 5-7 in Andosols, but >7 in Vitrisols (vitric Andisols of deserts, see Chap. 6.5). Histosols, which occur far from aeolian sources, can have pH down to 4. CEC is pH dependent and is generally high (10-40), but the un-weathered sandy Vitrisols have also considerable exchange capacities. Ca^{++} is by far the dominant cation. Icelandic Andosols have extremely variable carbon content, with undisturbed woodlands and wetland systems having >6% C in surface horizons, but Histosols have >20% C by definition. Carbon distribution with depth is erratic. The Vitrisols of Icelandic deserts are characterized by < 1.5% C. The Histic Andosols and the Histosols are a peculiar mixture of organic and andic wetland soils. There is a tendency of increased carbon per depth increment with distance from active aeolian dust sources. Restoration of desert areas leads to very rapid carbon accumulation in the soils (0.04 – 0.08 kgC m^{-2} yr^{-1}). Phosphorous retention is high, typical of Andosols as is pH measured in NaF, but the Vitrisols show lower values for P-retention and pH (NaF). Agricultural systems require considerable phosphorus applications. Oxalate extractable Al, Fe and Si are lower than in many Andosols of warmer climates, yet diagnostic criteria for Andosols are met. Pyrophosphate extractions indicate considerable formation of metal humus complexes, especially in organic soils with lower pH, but also allophane-hums bonding (at higher pH). Soil biology is discussed, and chemical data is presented for 9 pedons at the end of the chapter.



Chapter 9. Genesis and Mineralogical Characteristics

Soils of Iceland form in volcanic materials deposited by aeolian processes and as tephra deposited during volcanic eruptions. The surface is steadily rising, but the tephra materials weather readily to form clay minerals characteristic of volcanic areas: allophane of low Al/Si ratio, ferrihydrite and imogolite. High ferrihydrite contents result from high Fe in the parent materials. Each depth increment subsequently becomes buried under new aeolian and tephra materials, resulting in relatively little weathered horizons, but dependent on the rate of aeolian and tephra deposition. Poorly weathered materials with weathering fringes are dominant in the micromorphic fabric together with organic materials. Yet, the soils show strong andic soil character with high pH (NaF) and phosphorus retention. pH is moderately acid, depending on amount and weathering of aeolian/tephra materials. The soils accumulate organic matter, but the content per each depth increment is inversely related to amount of aeolian materials and depends on land use history (grazing etc) and drainage. Wetland soils are both andic and gleyic in nature, classified as Andosols near aeolian sources and volcanic systems, but further away, the organic content rises to Histic Andosols (>12% C) with Histosols (>20% C) in areas of low aeolian deposition. The allophane binds organic matter (higher pH), as does the formation of metal-humus complexes (low pH, high organic contents). Weathering of the poorly crystalline basaltic materials is very rapid, resulting in precipitation of Al, Si and Fe, with rates that are among the highest on Earth. Restoration of desert Vitrisols results in rapid organic accumulation (up to 0.07 kg C m^{-2} yr^{-1}).



Chapter 10. Frost and the Soil Environment

Frost has pronounced influences on soils and landscapes of Iceland. The soils are generally very frost susceptible, rich in silt. Colloidal constituents of the soils retain large quantities of water but behave like silt with rapid hydraulic conductivity and frost susceptibility. Winter temperatures are characterized more frequent freeze-thaw cycles than known elsewhere. The soils lack layer silicates (clays) that provide cohesion for soils elsewhere and they are easily deformed by frost. Many are phixotropic at high water contents. The soils are often heavily cryoturbated, but periglacial landforms characterize the landscapes, especially thufur (hummocks), solifluction features (terraces and lobes) and patterned ground on many deserts. Thufur occur in areas without a shallow water table, because of the combination of soil properties and climatic factors, often enhanced by grazing of animals. Needle-ice formation is extremely common on barren surfaces in winter, having pronounced effects on surface stability and negative effects on primary succession. Palsas occur in some highland areas. Permafrost is confined to the palsa features and very high elevations.

Chapter 11. The Volcanic Aeolian Environments of Iceland

Iceland has extensive unstable sandy deserts that shape the nature of all Icelandic ecosystems. Aeolian processes redistribute silty and sandy materials over the entire island, with large amounts deposited closest to active aeolian sources, such as near sandy deserts and more localized but very active dust plume sources. The most active dust sources are linked to glacial margins where glacial rivers deposit unstable silty and sandy materials on level sand plains, but also along level stretches of major glacial rivers. Most of the silty materials that make up the Icelandic dust are basaltic volcanic glass. Periodic volcanic eruptions add materials to the unstable barren surfaces. The sandy areas make up the largest volcaniclastic sand fields on Earth. Wind erosion rates in Iceland on unstable sand is often 500 – 3,000 kg m^{-1} yr^{-1}, but some of the most intense storms rate among the largest ever measured (>11,000 kg m^{-1} in one event). Dust deposition generally ranges from 0.01 to > 1 mm, with >500 g m^{-2} deposition within the most active areas, which is of the same order as the most active sandy desert areas elsewhere. The dust and volcanic ash deposition has a controlling effect on soil properties, soil genesis and ecosystem fertility, as discussed in other chapters of the book.

Chapter 12. Collapse, Erosion, Condition and Restoration

There is multiple evidence for dramatic ecosystem degradation after the arrival of man in Iceland about 870 AD. The woodlands and shrublands were nearly destroyed with massive soil erosion and degradation of the surviving vegetated systems. An attempt is made to introduce the various research efforts and methods from many scientific disciplines on the anthropogenic impacts on Icelandic ecosystems. Aeolian sedimentation rates are commonly employed, but need to be applied with caution. There is a large difference in the resilience and stability of the systems, with thinner (less aeolian deposition) and finer-textured soils far from aeolian sources and volcanoes more resistant to the degradation processes than thick coarse soils. These areas also have a large extent of relatively resilient wetlands and are presently with more vegetation cover than the active volcanic zone. Thick coarse-textured soils with coarse tephra layers near active aeolian sources and volcanoes have been subjected to massive erosion, leaving barren deserts behind in many areas. Land use reduced the stability and resilience of these systems to disturbances such as the cold spells of the Middle Ages and intermittent volcanic eruptions. Elevation is an important factor that reduces the resilience of ecosystems to land use. Soil erosion has been mapped for all of Iceland, showing both the continuous severity of the problem, but also vast differences between the different regions, soil types and ecosystems in terms of erosion problems. Land literacy is important in recognizing land degradation problems. A system for assessing the condition of Icelandic ecosystem is introduced. Revegetation and ecosystem restoration activities are an important part of environmental conservation efforts in Iceland, with many examples of successful projects. Iceland boasts one of the oldest Soil Conservation Agencies in the world (established 1907). Much of the destroyed systems can be restored back to full potential with time, but protection from grazing and facilitation by nitrogen inputs through direct applications and biological activity (including biological soil crusts) are important.