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SECTION I

ENGINEERING

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CHAPTER 1

THE INTERDEPENDENCE BETWEEN LOW pH AND HEAVY METAL STRESS AND ITS CRUCIAL ROLE IN CROP PRODUCTION EFFICIENCY

BRIGITTA TÓTH AND MAKOENA JOYCE MOLOI

Introduction

What is an abiotic stress?

A plant's natural growing habitat consists of not only optimal growing conditions but also abiotic and biotic stresses. Plant reactions to these stressors are combined in the same way. In this study, we focus on abiotic stresses. To survive, plants must deal with abiotic stressors such as soil salinity, low or high soil pH, water imbalance, and inordinate temperatures. The unfavorable effects of these stresses have increased as a result of climate change and unseasonal weather conditions (Fedoroff et al., 2010). Furthermore, humans also have a significant impact on these stresses, and consequently cause retarded plant growth and reduced yield.

Here, we review what is known about abiotic stressors, mainly focusing on low soil pH and its side effects, such as heavy metal and aluminum toxicity, on crop plants. This review will focus on the main metabolic processes, such as photosynthesis and respiration. Moreover, reduced growth and development will also be examined in relation to low soil pH.

Understanding stresses and plants' reactions to them will result in a greater ability to enhance stress resistance in plants with the purpose of achieving agricultural sustainability and food security for a growing world population.

Low soil pH

According to the United Nations Food and Agriculture Organization (FAO), "Acid soils are those that have a pH value of less than 5.5 for most of the year." On a rough estimate, 40–50% of arable lands have low pH (von Uexküll and Mutert, 1995), and about 60% of low pH soils are found in the tropics and subtropical regions.

Around 64% of tropical South America, 32% of tropical Asia, and 10% of Central America, the Caribbean, and Mexico are assumed to have low pH soil (Sanchez, 1977). Furthermore, enormous low pH regions are found in South Africa, where the annual rainfall is extremely low. Such areas contain largely rural communities. In addition, Ca, Mg, Mo, and P deficiencies often appear on crops in these areas (Beukes, 1995). The decrease in soil pH is also a significant environmental issue in Hungary (Várallyay, 2000).

According to the future prognosis, based on Schroeder et al. (1994), climate change – increasing temperatures – could result in further degradation/acidification because of increasing losses of organic matter, enhanced soil erosion and declining soil fertility levels.

Moreover, many developing countries are located in areas of low pH soil and suffer from Aluminum (Al) toxicity restricting crop production precisely where food security is weak.

Soil acidification is generated by several factors, as well as environmental and anthropogenic components, for example, acidic rain and the deposition from the atmosphere of acidifying gases or particles, such as sulphur dioxide, ammonia, and nitric acid, agricultural practice, fertilization and environmental pollution (Várallyay, 2005). In addition, Al is highly phytotoxic and has serious effects on the growth and development of plants in low pH soils (Matsumoto, 2000).

The three main reasons for soil acidification

1. Nitrogen fertilizer

The form of nitrogen and the fate of nitrogen in the soil-plant system is possibly the main driver of changes in soil pH in agricultural systems. Nitrogen (N) fertilization can considerably enhance plant productivity. However, it needs to be carefully managed to avoid negative environmental consequences. On the other hand, nitrogen pollution from agricultural systems has local, regional, and global environmental effects. For example, between 2000 and 2010, global land received more than 50 kg ha^{-1} N deposition (Penuelas et al., 2013), which has been well reported as the major reason for soil acidification (Yang et al., 2012). N-induced soil acidification has been a notable threat to species diversity and terrestrial ecosystem functioning (Chen et al., 2013).

Some previous studies have reported the effects of simulated N deposition on soil acidification (Hogberg et al., 2006; Horswill et al., 2008), and found that the magnitude of acidification varies largely among case studies or ecosystems (Lu et al., 2011).

The effect of nitrogen on soil acidification depends on the form of fertilizers applied. Nitrogen can be applied in different forms, but the two major forms of N fertilizers used are urea and ammonium nitrate. The key molecules of N contributing mostly to changes in soil pH are the uncharged urea molecule ([$CO(NH_2)^2$]), the cation ammonium (NH_4^+) and the anion nitrate (NO_3^-). The conversion of N from one form to the other involves the generation or consumption of acidity. Also, the uptake of urea, ammonium or nitrate by plants will also influence the acidity of the soil (Fig. 1).

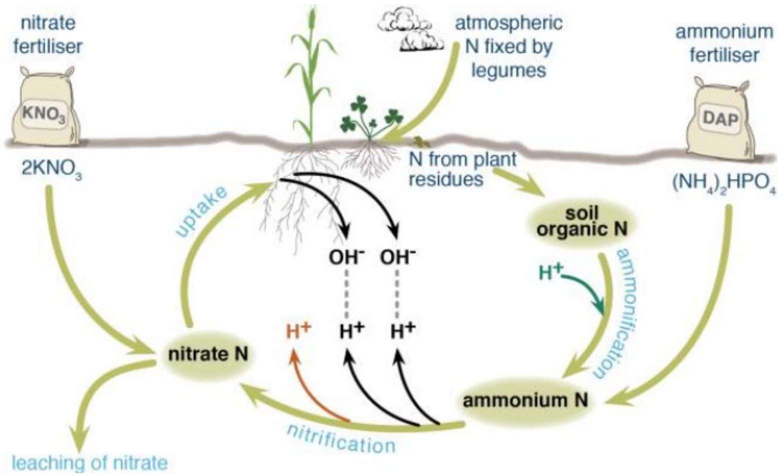

Figure 1: Different forms of nitrogen fertilizers in the nitrogen cycle (Source URL 1)

2. Acid rain

The pH of rain is 5.6 which is acidic, while acid rain has a pH from 4.0 to 4.2 in the United States (Mohajan, 2018). The contributing factors to rain acidity include emissions of sulfur and nitrogen dioxide. In addition, nitrogen is the major pollutant, and very harmful to human health. For this reason, the United States decreased sulfur dioxide emissions by 88% between 1990 and 2017 according to EPA (I 1); the decrease was 90% from 1980 to 2017. China has also decreased such emissions by 75% since 2007, but unfortunately, emissions of sulfur dioxide increased by 50% in India (Li et al., 2017).

3. Intensive agriculture and monoculture agricultural production

One of the main goals of farming is to expand crop yields and minimize costs. The most successful way of achieving both is monoculture farming. However, this also has some disadvantageous impacts, especially on soil. For example, monoculture agricultural production results in nutrient deficiency in soils, leading to nutrient deficiencies in crop plants as well. To compensate for these deficiencies, farmers use more and more fertilizers which have negative effects on the environment. The influence of the use of high amounts of nitrogen fertilizers has been mentioned above. Furthermore, longstanding cropping systems often cause changes in the physical, chemical and biological properties of soil, which can generate changes in the functional quality of soil.

Influence of low soil pH on heavy metal and aluminum toxicity

Al toxicity is a primary factor limiting crop yields in low pH soils. Inter- and intra-specific contrasts in tolerance to Al and growth and development under phytotoxic levels of Al either in soils or in nutrient solutions have been extensively researched (Foy, 1983; Simon et al., 1994; Baligar and Fageria, 1997; Tóth et al., 2013).

While there is notable proof for differential Al tolerance among plant species and cultivars within species (Foy, 1984), the precise mechanisms of Al toxicity for cell growth remain undefined (Matsumoto, 2000; Arroyo-Serralta et al., 2005). Even so, many research studies have already proposed that Al toxicity influences biochemical and physiological processes, for instance:

1) cellular and ultrastructural changes in leaves and roots (Ozyigit et al., 2013; Riaz et al., 2018);
2) changes in protein composition (Li et al., 2016);
3) inhibition of CO_2 assimilation (Jiang et al., 2009);
4) modifications in chloroplasts, photosynthetic pigment content, and light absorption (Chen et al., 2010);
5) alteration in photosystem I (PSI) and II (PS II) (Yang et al., 2015);
6) changes of stomatal parameters (as well as: density, index, length,

width, shape coefficient, and surface) and closure (Smirnov et al., 2014);
7) changes in stomatal conductance and transpiration (Ribeiro et al., 2013);
8) changes in superoxide-dismutase activity and rate of lipid-peroxidation (Zhang et al., 2007);
9) influence on DNA replication (Jaskowiak et al., 2018); and
10) induction of chlorosis and leaf necrosis on the leaves (Roy et al., 1988).

Influence of Al toxicity on photosynthesis

Based on Baker (2008), the rate of variable fluorescence and maximum fluorescence specifies the influences of biotic or abiotic stressors on photosynthesis. Furthermore, a linear correlation was detected between a decline in Fv/Fm and the optimal photosynthetic quantum yield (Krause and Weis, 1991), indicating that alterations in Fv/Fm values can be connected to changes in the quantum efficiency of photosynthesis. Al toxicity is associated with a severe decrease in the photosynthesis capacity of different plants such as maize (Mihailovic et al., 2008) and lemon (Pereira et al., 2000).

One of the expected reasons for the reduction in the net photosynthesis could be the structural damage to the thylakoids, which influences the electron transport chain, described by the diminished ratio between variable fluorescence and initial fluorescence (F_v/F_0) (Pereira et al., 2000).

Influence of low pH on respiration

Enzymes are most active at optimal pH, and they are affected by changes in pH. In addition, pH also controls ion uptake which has an influence on cellular respiration. The main result of decreasing soil pH or so-called soil acidification is that the insoluble form of aluminum becomes soluble. This form influences cation uptake and root organic acid excretion. These mechanisms are enhanced, while cell division and root growth are retarded.

It takes a great deal of effort to evaluate exactly the extent of several forms of respiration (e.g., dark respiration, photo-respiration, including non-phosphorylating respiration and alternative respiration). The number of individual reactions of the respiratory metabolism that are set in various cellular compartments is influenced directly by cytosolic and/or organelle pH.

Respiration is one of the most important catabolic mechanisms in plants:

1) Root respiration depends on the rate of growth and nutrient supply to the roots, both of which are influenced directly by changes in soil pH (Van der Werf et al., 1992):

   - long-term effects: a smaller growth rate => a lessening of ion absorption and transport at => root respiration;
   - fast and direct effects: inhibited hormones and protein synthesis;
   - acid soil => increased CO_2 concentration in the soil => inhibition of mitochondrial enzymes => decreased root respiration;
   - low soil pH => affects soil life => effect on nutrient uptake and root respiration.

2) Leaf respiration influenced by three components: continuation of biomass, growth, and transfer of nutrients (Lambers et al., 1998). Soil pH has the biggest effect on the latter.

Effect of Al toxicity on respiration

Soil pH determines the total amount of Al that is solubilized, and therefore available for physiological effects; it also influences the inorganic forms of Al that define its toxicity.

Physiological research into the metabolic effects of Al especially target its influence on photosynthesis (Clijsters and can Asscche, 1985) and, more recently, on specific gene expression (Tomsett and Thurman, 1988). On the other hand, there is an absence of reported observation linkage between Al and respiration.

Many researchers have reported the effect of Al toxicity on respiration, in the case of different plant species. Yamamoto et al. (2002) report an extension in reactive oxygen species, declined respiration and reduction of ATP in pea roots 12 hours after Al exposure. Al-inhibited respiration was observed in cut rose leaves by Son et al. (1994) and inhibited mitochondrial respiration in rice roots (Hao and Liu, 1989). Furthermore, dark respiration was retarded in Japanese red pine when Al was applied to the growing medium (Lee et al., 2001).

Three main influences of Al on plant respiratory metabolisms were observed:

1) effects directly influenced by the interactions with the plasmalemma and organellar membranes (Yamamoto, 2018);
2) effects connected to the uptake of ions (Rahman et al., 2018); and
3) effects linked with Al-induced efflux of organic acids (Saber et al., 1999).

Influence of low soil pH on plant growth and development

Low soil pH decreases plant growth in many ways:

1) nutrient deficiency (e.g. P, Mo, Ca); and
2) heavy metal and Al toxicity.

1. Influence of nutrient deficiency on plant growth and development

The synergy between plant roots and soil microorganizms, especially with mycorrhizal fungi and non-symbiotic plant growth promoting rhizobacteria, plays an important role in nutrient availability and the mechanisms that are related to plant growth promotion (Richardson et al., 2009). Accordingly, microbial activity in the rhizosphere contributes significantly to plant growth by enhancing the bioavailability of the soil-borne nutrients. Such activity, however, is highly dependent on the soil pH. Most of the nutrients, for example nitrogen, phosphorus, and sulfur, are found in organic molecules and they are moderately available for plants. In order for these nutrients to be available for uptake by the plant, soil microbes such as bacteria and fungi are needed because they have the metabolic machinery to depolymerize and mineralize organic forms of N, P, and S. “The contents of these microbial cells are consequently released, either through turnover and cell lysis, or via protozoic predation” which “liberates inorganic N, P, and S forms into the soil, including ionic species such as ammonium, nitrate, phosphate, and sulfate that are” more useable “nutrient forms for plants”. Such microbial nutrient transformations are important drivers of plant growth (Jacoby et al., 2017).”

Although pH plays a very important role in regulating microbial growth in the soil, it is not the only regulator factor in the case of bacteria diversity (Cho et al., 2016).

Although individual nutrient availability varies with pH, plants growing in highly acidic soils are prone to nutrient deficiency which can affect plant growth and development in the following ways:

1) **Calcium**: although calcium "is a component of many primary and secondary minerals in soils," its "availability to plants occurs only in the soluble Ca2+ form". In highly acidic soils, the free Ca2+ form is often low for different reasons, making the soil calcium deficient (Marschner, 1995). This will affect plant growth because it is required for several "structural roles in the cell wall and membranes as a counter - cation for inorganic and organic anions in the vacuole, and as an intracellular messenger in the cytosol" coordinating the plant's developmental responses (White and Broadley, 2003).
2) **Potassium**: Potassium makes a significant contribution to plant growth and development because it plays an important role in several physiological activities such as enzyme activation, stomatal activity, photosynthesis, transport of sugars, and protein and starch synthesis. It also affects crop quality (Prajapati and Modi, 2012). In highly acidic soil solutions, potassium concentrations are diminished, which may lead to K^+ deficiency in plants. Also, "under acidic conditions, most of the other major cations are in very low concentrations" (Marschner, 1995), which increases the threat of potassium deficiency rather than toxicity. In some *H. lanatus* and *B. pendula* varieties, highly acidic soils inhibited root and shoot elongation along with reduced potassium concentrations in the roots (Kidd and Proctor, 2001).

3) **Phosphorus**: In spite of the fact that soils contain huge amounts of phosphorus, only a slight percentage of total phosphorus is useable by plants. Plants uptake P in the form of orthophosphate anions (HPO_4^{2-} or $H_2PO_4^{1-}$) from the soil or nutrient solution, depending on the growing medium. The concentrations of these anions are low in most soils (Richardson et al., 2009). Plants' "response to P deficiency is reduced shoot growth rate (Lynch et al., 1991) which manifests itself by a change in the carbon partitioning causing an increase in root/shoot ratio that provides a relatively larger root system for more effective P acquisition from the soil (Smith, 2001)" (Lauchli and Grattan, 2012).
4) **Nitrogen**: Every plant uses nitrogen (N) in the form of NO_3^- and NH_4^+. Nitrogen makes a very significant contribution to several physiological processes. It is responsible for the dark-green color in plants, and it contributes to the growth and development of leaves, stems, and other vegetative parts. In addition, nitrogen also enhances root growth. Nitrogen causes rapid early growth, enhances fruit quality, expands the growth of leafy vegetables

and increases the protein content of fodder crops. It encourages the uptake and utilization of other nutrients such as potassium, phosphorous and it regulates the general growth of plants (Leghari et al., 2016).

5) **Iron (Fe)**: Iron is one of the essential trace elements in plants because it plays a significant role in various physiological and biochemical processes, for example, the synthesis of chlorophyll and maintaining chloroplast structure and function. An imbalance between its solubility in the soil and the demand by the plant leads to Fe deficiency (Rout and Sahoo, 2015). Among the important factors reducing Fe availability in the soil solution is the soil pH, where higher pH is more significant (Abadía et al., 2011).

Plant characteristics such as height, lateral spread, fresh and dry weight, flower size and number, pollen production, and many others are also influenced by soil pH (Jiang et al., 2017). This, however, varies with plant types. For example, in sago palm planted at different pH ranges, plant growth, leaf emergence, leaf senescence, and total leaflet area were similar. In addition, no outstanding influence of pH was observed on the dry matter weight, even though it should have been lighter at pH 3.6 than at pH 5.7. Similarly, the photosynthetic rate and its related parameters were not significantly influenced by the pH. However, the photosynthetic rate was lower when plants were grown at pH 3.6 compared to pH 5.7 growing conditions, which also caused reduced stomatal conductance. Also, no effect of low pH was reported on the uptaken nutrient concentration (Anugoolprasert et al., 2012).

In contrast, *A. artemisiifolia* plants grown at pH 7 were shorter and developed leaves at a slower rate compared with plants grown at pH 5 and pH 6. The plants at lower pH were fertile, contrary to infertile pH 7 grown plants. Also, at pH 5 and pH 6, plants had both larger and more various inflorescences and emitted pollen earlier (Gentili et al., 2018).

Ryegrass reacted in various ways to a 4.2–7.0 pH range. The concentration of measured elements was lower at low pH and a linear increase was observed parallel with increasing pH. Moreover, the sensitivity of elements was dissimilar. Cu was more sensitive to changing soil pH (4.2–7.0) compared to Ni and Zn. Also, an increment was found in yield that can be explained by the higher Zn content in ryegrass (Smith, 1994).

This information emphasizes the importance of plant adaptation to H+ toxicity in very acidic soils.

2. Effect of heavy metals and Al on plant growth and development

Many researchers have reported that heavy metals have a negative effect on plant growth and development (Ackova, 2018; Ashfaque et al., 2016; Athar and Ahmad, 2002; Ghani, 2010), in some cases, growth was inhibited but dry weight was not reduced significantly (Chaves et al., 2011).

Al toxicity is an important prohibiting circumstance in plant growth in low pH growing conditions. The first severe influence of Al is the inhibition of root growth (Foy, 1988) within a few hours of Al treatment (Blamey et al., 2004). The crucial site of Al perception and response in the root apex (Ryan et al., 1993) and, especially, the distal part of the transition zone (1–2 mm) is the most Al-sensitive apical root zone (Kollmeier et al., 2000).

Al toxicity, like other environmental stresses, induces the formation of reactive oxygen species (ROS) in plant cells (Breusegem et al., 2001). Under optimal growing circumstances, cells produce ROS by means of the degradation of molecular oxygen (Hippeli et al., 1999). By contrast, when plants are influenced by biotic or abiotic stress, the production of these molecules is enhanced. However, most of the cells have a detoxification system, consisting of several enzymes like catalase (CAT), superoxide dismutase (SOD), peroxidase (POX), and reductase. These enzymes efficiently reduce ROS under optimal growing conditions. But, if complete reduction does not happen, as under conditions of enhanced production, the outcome may be a state of oxidative stress causing the degradation of lipids and proteins (Schieber and Chandel, 2014).

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CHAPTER 2

TECHNICAL AND ADMINISTRATIVE APPROACHES IN FLOOD MANAGEMENT

ASLIHAN KATIP

Introduction

Floodplains have increasingly become settlement areas because of rapid population growth and industrialization. Human activities such as urbanization, deforestation, and agriculture have brought about changes in water storage (leakage and water permeability) in the basin. In addition, climate change, coupled with unpredictable economic and social policies has elevated the risk and danger levels of possible floods (Ellis et al., 2008; Üyüklüoğlu, 2015). As part of the effort to mitigate the impact of floods, flood management plans have been crafted in Turkey and around the world which have a vital role to play, particularly in cities. In addition to structural measures, management studies employ several software tools and geographic information systems to draw hazard and risk maps, which have gained tremendous importance (Thieken et al., 2016). This study aims to review both Turkish and international studies on flood management and to suggest methods to deal with their detrimental effects. To this end, the term flood is expounded, and its environmental benefits and harms are discussed in detail. The study gives a further account of flood management studies in Turkey and across the world, and elaborates on some of the methods employed.

Flood

A flood occurs when the amount of water that moves on a river bed (flow rate) increases and results in the overflow of the water, thereby damaging surrounding land, property, and people (Balcı, 1984). Temporary ponding that starts on shores, spreads to flat and holed zones, and impacts other areas in the basin, is what we call a flood (Turoğlu, 2005). Today, the most commonly used definition of flood is given in the EU's Directive 2007/60/EC: "Flood is the temporary covering by water of land not normally covered by water." This definition encompasses river and slope floods, dry river floods peculiar to the Mediterranean Region, and sea floods in coastal areas. It excludes floods induced by wastewater systems (EU, 2007).

Floods can be grouped based on their duration of occurrence, seasons, and locations. The period spanning from the precipitation of rain and snow to their conversion into flowing liquid sets the flood occurrence time. Those that take a long time occur in a week or more, while sudden floods can brew in just six hours. Seasonal floods, on the other hand, are triggered by downpours and melting glaciers or snow in summer. Precipitation occurring between November and March in winter and between April and May in spring may also lead to seasonal floods. The area of occurrence is determined by the type of water body where the flood originates, which can be rivers, coasts, mountainous areas, groundwater, or lakes (Anonymous, 2017). Floods occur frequently on river banks in cities. River corridors that make up the area that can affect other nearby areas should be arranged properly, and rivers and cities should be organized together (Özdemir, 2013).

Flood-causing Factors

Factors that induce floods are classified as physiological and meteorological:

- Physiological factors include the size of the basin, the river bed, the frequency of river tributaries, the shape and ruggedness of the river, natural and artificial lakes, the elevation of the area as well as its topography, geology, vegetation, and land use.
- Meteorological factors are the intensity, amount, and duration of precipitation; the direction, type, and volume of the storm; and aridness of the region (Özdemir, 1978).

Physiological Factors

Size of the Drainage Area: The water-collecting area in a river basin is named the drainage area. The magnitude of a flood goes hand in hand with the period until the peak value, flood volume, and drainage area. According to the literature, this ratio is two to three, the force of the drainage area and varying surface flow coefficient.

Shape of the Drainage Area: Volumes of the flood stemming from drainage areas of the same size and characteristics but with different shapes could be equal; however, the flood flow rate and the period until the peak value could well differ based on the shape of the basin.

Drainage Area Slope: The drainage area slope plays a critical role in floods. Although flood volumes of two drainage areas with the same surface area and equal characteristics are the same, the flood flow rate of the drainage area with higher slope is greater, and its time span until the peak point and flood duration are both shorter. The slope of the drainage area is the same as the slope of the main river. That said, calculated flood flow rates always remain lower than expected in the event that the harmonic slope of the main tributary of a river is significantly lower than the general slope of the basin. Accordingly, calculations that divide the basin into tributaries should be made in a way that takes into account periods of delay and draws on superposition and postponing so that future flood flow rates of the basin can be more accurately predicted.

Geological Structure of Drainage Area: In line with the ground permeability, the geological structure of the drainage area is of particular importance in determining the scale of possible floods if the soil cover is flimsy or non-existent or residential structuring is notable. Precipitation seldom transforms into surface flow in fissured, cracked, faulted, or highly permeable land where metamorphic rocks lay in abundance. Ponors, tunnels, and caves in karst lands allow flows to quickly empty into groundwater or different drainage areas, thereby reducing floods.

Storage Capacity of the Drainage Area: Collection of surface flow in natural coves, ponding in flat or slightly sloping areas, and at times the occurrence of flood zones due to the spread of surface flow considerably curb flood peaks and extend the periods on flood hydrographs.

Vegetation in the Drainage Area: The vegetation in the drainage area affects in particular the initial losses that occur during the process prior to the transformation of precipitation into surface flow. This effect determines the amount of precipitation that the vegetation can absorb and hold, based on the type, frequency, and size of vegetation and even on the shape of leaves predominant in a given area. In short, vegetation plays a pivotal role in preventing floods and erosion.

Soil Coverage in the Drainage Area: The effect of the soil type and thickness on initial losses is even greater than that of vegetation. In fact, the soil type is the most important factor in terms of leakage, so it serves a critical function during the course of a flood.

Use of the Drainage Area: Use of the drainage area is another element that influences the occurrence of floods in rural and urban areas. A large proportion of the precipitation falling in a complete forest is absorbed by plants. A certain amount naturally evaporates, while some of it penetrates into groundwater and is stored but does not mingle with surface flow. However, vegetation in densely populated urban areas fails to catch and store the flow, and permeability is insufficient, which is why large water masses quickly join surface flow and may spark floods. Figure 1 shows the use of a drainage area and its impact on infiltration and runoff.

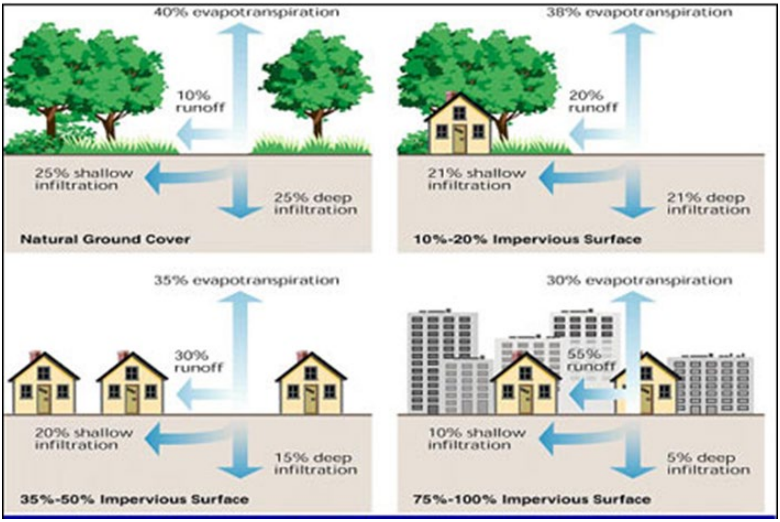

Figure 1: The use of a drainage area and its impact on infiltration and runoff (USEPA, 2019)

Elevation of the Drainage Area: Because the dew point remains low at high altitudes and the water content of the basin is low at lower dew points, areas with high elevation are exposed to less intense but longer precipitation. However, coast-facing slopes stretching perpendicular to the direction of precipitation in particular receive a larger amount of rainfall or snow than drainage areas with their back to the direction of the precipitation.

Artificial Structures in the Drainage Area: Water structures such as dams, ponds, and flood detention dams preclude floods in the drainage area. Additionally, improvement of seawalls, canals, and stream beds could impact floods in either a positive or negative way. The impacts of these structures should be studied meticulously and evaluated carefully.

Hydrogeology of the Drainage Area: Lakes, swamps, and springs in the drainage area increase evaporation which results in more precipitation. In a way, these formations tend to boost floods as the close proximity of the surface water level to the surface complicates leakage and permeation. On the other hand, lakes and swamps significantly mitigate the impacts of floods because of their storage feature.

Humidity of the Drainage Area: The humidity status of the drainage area surface prior to the flood largely determines the effect of precipitation on the surface flow that occurs in the basin. Flood-inducing precipitation is highly likely to trigger leakage on a dry surface. In this case, precipitation does not translate into surface flow. On a saturated surface, however, the leakage capacity remains low, and the flow can transform into a surface flow.

Meteorological Factors

Intensity of precipitation: The amount of precipitation per unit of time is called the intensity of precipitation. In general, floods are brought about by heavy precipitation. As severe precipitation does not leave enough time for leakage and surface flow gains momentum, higher intensity of precipitation aggravates floods.

Duration of precipitation: As precipitation falling at a steady intensity continues for extended periods, the magnitude of a resulting flood reaches a limit based on the area of the catchment basin, collection time, and certain other aspects of the basin. Even if the precipitation lasts forever, its peak level remains unchanged although the volume of the flood grows. If the intensity of precipitation varies, the flood peaks during the highest precipitation period.

Type of Precipitation: Precipitation in a given area may be in the form of rain, snow or hail. The rain gives rise to the flood by filling the stream bed in the catchment basin and causing a surface flow. The snow displays its impact once it begins to melt. During this phase, surface and ground water increase considerably in volume. The hail commonly falls when surface temperatures remain above 0°C, which is why it melts swiftly and transforms into the surface flow in a short amount of time (Kadıoğlu, 2012).

Detrimental Impact of Floods

There are three categories of detrimental impact caused by floods: direct, indirect, and intangible damage. Direct damage refers to the physical impact of loss of life and property and degradation of the environment. The velocity and depth of the amount of water in the flood area determine the severity of the direct impacts (Anonymous, 2017). Indirect damage