SOIL FERTILITY PROBLEM IN WATERSHED MANAGEMENT(*)

(A Review)

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The soil as an integral part of a watershed, and its importance in the management of watershed, deserves the focus of our attention. Moreover, soil fertility as a function of wareshed management has an intimate correlation with the management purposes in a given area. This paper will briefly cover this problem.

I. Watershed Management and Its Objectives

More recently watershed management has been used as a more suitable and popular term. **It has been defined as the administration and regulation of the aggregate resources of a drainage basin for the production of water and the control of erosion, streamflow, and floods** (9). For the control of erosion or the stabilization of moving sands, or the reduction of flood damage, natural vegatation protected from fire usually serves the purpose. When the objective of producing a maximum yield of usable water is introduced, however, it can not be assumed that the unmanaged natural vegetation will be the most effective in contributing to the greatest amount of water.

Four phases of watershed management may be recognized: (9).

(1) First is the recognition phase, which involves a survey to determine content, location, and severity of deterioration on critical or misused areas.

(2) The second is the restoration phase, which includes the correction of the unstable conditions causing erosion and floods by vegetation or engineering methods.

(3) The third is the protection phase, which involves not only protection from fires or damaging agencies but the maintenance of existing conditions, provided they are acceptable for the uses to which the area is subject.

(4) The fourth is the improvement phase, when practices are initiated to increase the yield of water.

(*) This is a review compiled from the literature cited.

Of course the objectives of watershed management are to hold erosion at acceptably low levels, to exert the maximum practicable control over those water flows that contribute to floods, and to increase the yield of usable water.

II. Importance of Soil Fertility as a Watershed Problem

It is obvious that the soil in a watershed supplies mechanical support and, in part, sustenance for plants. In compliance with the objectives given above, the adequate vegetative cover is mainly effected by the soil fertility.

If we go in to the definition of soil fertility vs. productivity, there is no generally accepted concept of the term «fertility» as applied to soils. Some scientists consider that a fertile soil must supply in reasonable amounts and in suitable balance, all the nutrients which a plant takes from the universal and organic soil fractions and also be located in the climatic zone which provides moisture, light, and heat sufficient for needs of the plants under consideration. Also, toxic materials must not be present in sufficient quantities to limit growth appreciablly, and soil structural conditions must be reasonably satisfactory. Naturally, the textural make-up of a soil has much to do with its capacity to supply adequate moisture under a given climatic condition (11).

It is generally agreed that a soil such as described is both productive and fertile. But are all the conditions described necessary for a soil to be considered fertile? Some scientists maintain that the above described soil would be fertile even if located in a region of low rainfall because all that is needed to make it productive is the application of water. In other words, ability to supply adequately the nutrients normally taken form the soil by plants, moderated with freedom from toxic materials, is taken as sufficient basis for **designating a soil as fertile but not productive.** In this concept, environmental conditions such as temperature, light, precipitation, and drainage are ignored. The idea of potential capacity to produce crops is involved. Although this is a limited interpretation of the term it is one held by many American scientists. In conversation with farmers there is a tendency to use the words **productive** and **fertile** synonymously (11).

In this article we will use the term soil **fertility** as a factor referring to the soil properties or capacity to support plant growth in a watershed area, synonymous with the productivity concept.

Thus, the term **soil fertility** refers to all favorable properties of soils both physical and chemical for plant growth in a given area. Of course

all higher plants have the same basic requirements for growth, though in widely varying amounts or degrees. They are light, heat, water, air, and certain nutrient elements. The soil must supply the needed moisture and nutrients, with the exception of carbon dioxide. Also, the soil is intimately concerned with the control of temperature both in the root zone and around the areal portion of plants. In productivity studies soil moisture and air must be considered integral parts of the soil even though the composition and qualities of them are constantly changing.

Knowledge about the characteristics of the soil and substratum is of prime importance in all aspects of watershed management (16). Certain properties inherent in the soil and in the rock beneath set limits to what can be done in controlling waterflow and erosion. Some soils, for example, have low percolation rates regardless of what treatment they receive because they are fine textured, have restricted soil permeability, or have impervious bedrock beneath. Some are peculiarly subject to surface sealing when denuded and consequently require a kind of land management that maintains a protective plant cover. There are soils that inherently resist erosion and others that do not. This difference, too, influences what can be done in managing land for watershed purposes.

The capacity of the soil to hold water is another property important in watershed management. Factors affecting storage capacity are soil depth and the texture and structure of the soil harizons.

Another most important aspect of soil fertility is the soil erosion problem in the watershed. It is well known that, fertile and productive soils have dense and adequate vegetitive cover. Though, as Lyon, Buckman and Brady stated in their book, «One of the most important and at the same time the most **underrated means of erosion control is the maintenance of high soil fertility and productivity.»**

III. Factors Affecting the Soil Fertility and Productivity

A. The Physical properties of soils

Soils are classified and mapped generally on the basis of physical characteristics which the surveyors can recognize by visual inspection. Many of the important chemical and biological properties are reflected by the physical properties of the soil (16). Furthermore, the physical properties of soils determine to a large extent their productive capacity. The aeration and moisture relations, as well as area of root penetrations, are determined largely by the physical make-up of the soil profile.

Physical properties emphasized in this paper are texture, structure, porosity, color and waterholding capacity.

a) **Soil Texture :** Texture refers to size of soil particles. Based on size of soil particals there are three fractions: sand, silt, and clay.

Clay fraction with humus more or less intimately mixed, constitute most of the colloidal matter found in soils. Of course, most soil reactions whether physical, chemical, or biological, depend in large degree on the colloidal nature of certain major constituents, both living and non - living.

In a broad way, two groups of clays are recognized - the silicate clays so characteristic of temperate regions, and the iron and aluminimum hydrous oxide clays found in the tropics and semitropics.

On the basis of their crystalline properties three general groups of silicate clays are now recognized (10).

1) Kaolinite $Al_4\ Si_4\ O_{10}\ (OH)_8$

2) Montmorillenite $Al_4\ Si_8\ O_{20}\ (OH)_4$

3.) The hydrous micas of which **illite** is representative $KAl_2\ Si_4\ O_{10}\ (OH)_2$

The clay crystal has a negative electrical charge, which gives it the capacity to hold positively charged cations. One gram of clay will have hundreds of thousands of crystals, and the chemical analysis of the clay will show a large number of different kinds of cations such as H^+, Ca^{++}, Mg^{++}, K^+,Na^+, and NH_4^+.

Clay acts as a weak acid and may be compared to the bicarbonate radical for (HCO_3^-).

Thus, they have negative charges and hold cations. This base (or cations) exchange capacity of montmorillenite is higher than that of illite, and higher than that of kaolinite.

Clay	Exchange Capacity M. E./100 g.
Montmorillenite	80 — 100
Illite	20 — 40
Kaolinite	3 — 15

(Thompson : Soils and Soil Fertility)

Table 1. Exchange capacity. Exchangeable Bases and Exhangeable Hydrogen in Tama Silt soil A Prairie **Soil**.

Horizon	Depth in	Exchangeable Cations Ca	Mg	K	H	Base Exhange Capacity
A_1	0 — 1½	26.24	4.51	1.14	1.35	33.29
	1½ — 3	17.83	3.99	0.77	1.61	24.20
	0 — 4	13.07	3.80	3.38	4.44	21.75
A_3	15 — 18	10.05	4.06	0.28	8.21	19.60
B_2	24 — 27	12.09	6.35	9.42	3.38	22.24
B_3	33 — 36	12.07	5.18	0.36	3.94	21.55
C_1	42 — 45	12.24	5.57	0.40	0.93	14.32

Values are in miliequivalents per 100 g. overn dry soil. R. W. Simonsen, unpublished data.

(Thompson : Soils and Soil Fertility)

Table 1. shows the exchange capacity for different layers of soil profiles. The Tama profile shows a reduction in exchange capacity from the top of the A horizon to the bottom of the B horizon, a change which is due largely to decrease in organic matter from the A to the B horizon. At the same time any horizon differentiation has the effect of decreasing the clay content of the A horizon and increasing the clay content of the B horizon; therefore, if the organic matter were removed from the Tama profile, one would expect a higher exchange cpaacity in the B horizons than in the A horizons (16).

Consequently, the cation exchange capacity would be changed according to the soil type, the type and amount of clay fraction in the soil and the different horizons through the profile. In compliance with this fact, the fertility would be changed. For instance, the cation exchange capacity of hydrous oxide clays of tropical region is exceptionally low, being somewhat less than of the kaolinitic group-

This has a fertility bearing of no major importance. Another fertility relationship is the large amount of active iron and aluminum present. These cations tend to render phosphorus, both native and added, notably unavailable to plants, a feature not bo be lightly regarded.

b) Organic Matter : Influence of soil organic matter on soil properties can be summarized as follows :

1. Effect on soil colar ..... brown to black.

2. Influence on physical properties
   a. Aids in the development of the desirable granular or crumb structure in soil.
   b. Plasticity, cohesion, etc. reduced.
   c. Water holding capacity increased.

3. Increases the capacity of the soil to hold exchangable ions.
   a. Two to thirty times as great as universal colloids.
   b. Accounts for 30 to 50 per cent of the adsorbing power of mineral soils.

4. Humus increases the stability of aggregates and helps increase the rate of infiltration of water into soils, thus reducing run - off and erosion.

5. Supply and availability of nutrients.
   a. Easily replaceable cations present.
   b. N. P. and S. held in organic forms.
   c. Extraction of elemants from minerals by acid humus.

The most important factors affecting the amount of organic matter in soils are; kind of vegetation, tapography, nature of the parent material of soil, climate and time.

Organic matter is distributed in the soil in accordance with the distribution of the residue turned over to the soil by the plant. Since the root

system of grasses is concentrated near the surface and gradually decreases in extent with increasing depth, the organic matter content is greatest near the surface and gradually decreases downward. On the other hand, the roots of trees are not concentrated at the surface and are deeply distributed. Since the tree supplies most of its organic material as leaf fall, the organic matter tends to accumulate at the surface (8).

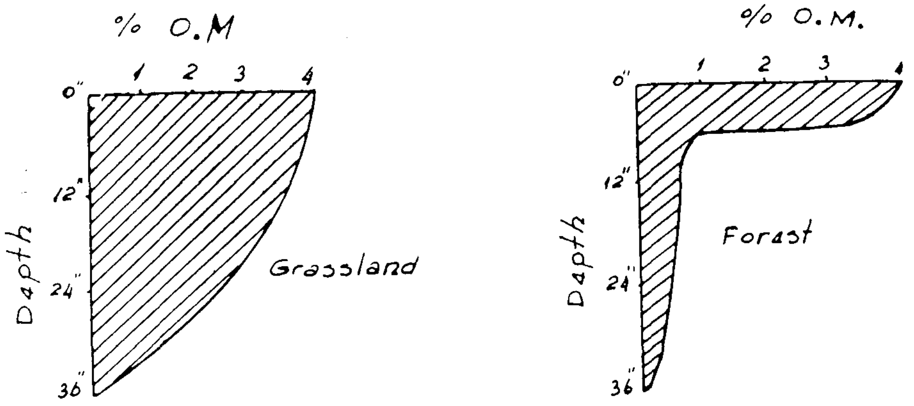

Figure : 1. The distribution of organic matter in typical soil profiles. (Thompson : Soil and Soil Fertility)

The omportance of the forest floor in the nutritional cycle of a forest community is widely recognized. Nutrients stored in the various components of the forest floor are intimately related to the maintenance of soil fertility in o forest ecosystem. Studies by Romell and Heiberg (1931), Romell (1935), and Cole and Gessel (1963) have indicated that silvicultural treatments have a great influence upon the release and cycling of these elements and that foresters should recognize this nutrient reservoir. The forest floor also affects soil erosion, forest hydrology, and soil biology, but not all relationships are understood (4). Balci (2) reports in Table 2 that the mean total weight of mor forest floor components is greater than that of duff mull layers.The total weight of mor forest floor, 157.9 metric tons per hectare is not significantly greater than the duff mull total weight (103.4 metric tons/ha.). Large quantites of nitrogen, phosphorus, potassium, and carbon are stored in the forest floor (2). The 2,040 Kg./ha. nitrogen in mor and the 1,393 Kg./ha. in duff mull far exceed the annul requirement of a forest stand as estimated by Heilman and Gessel. The magnitude of elemental storage suggests that forest floor should be given consideration in forest ecosystem studies. In fact, the authors have observed many instances in which roots of forest stands were mainly confined to the forest floor (4).

TABLE 2. Summary of elemental content of mor and duff mull forest floor types of western Washington old-growth coniferous forests

Forest floor types	Oven-dry weight	Total nitrogen	Total phosphorus	Total potassium	Total carbon
	kg./ha.	kg./ha.	kg./ha.	kg./ha.	kg./ha.
Mor					
L	14,431	161.7	14.9	14.1	7,038
F	22,449	313.2	24.5	23.8	10,743
H	121,004	1,565.1	102.2	89.2	58.465
TOTAL . . .	157,884	2,040.0	141.6	127.1	76,246
Duff mull					
L	13,657	171.0	15.2	14.6	6,562
F	17,971	266.2	22.2	21.1	7,988
H	71,722	956.2	77,2	67.1	28,728
TOTAL . . .	103,350	1,393.4	114.6	102.8	43,278

(BALCI, 1964; Physical, Chemical and Hydrologic Properties of Certain Western Washington Forest Floor Types).

Thus, it is obvious from the explaination above that the amount of organic matter is affected by the vegetation type and vegetation type itself has an indirect effect on the soil fertility in a given area.

c) **Soil Structure :** It has been realized for many years that soil structure is one of the important factors limiting crop production and vegetative growth on heavy textured soils in an area. It has also been realized that soil structure is one of the important factors in soil erosion, and is an important factor effecting the soil fertility.

B. Chemical Composition of Soils

Soils include mixtures of many rocks and minerals of various sizes and in different stages of weathering. Chemical decomposition of rocks and minerals occurs along with disintegration. While disintegration is merely the reduction in size of praticles or fragments, decomposition results in change in chemical composition. Chemical decomposition is necessary in order to release ions and simple compounds for use by plant life. There is no doubt that a fertile soil containing considerable fresh rock and minerals is rapid enough to supply needs for large crops.

Different minerals vary grealty in the rate at which they weather. Potassium - bearing minerals generally weather very slowly compared to calcium - bearing minerals. Quartz is one ot the common minerals most highly resistant to weathering, and as a consequence, is the most abundant mineral in the sand fraction of soils.

As minerals and rocks weather and the more soluable materials are leached away, there is an accumulation of more resistant materials. Of the products of decomposition, the oxides of silicon, iron, and aluminum are most resistant to leaching, and these three components accumulate during weathering. Table 3 shows the chemical composition of fresh amphibolite and its residual clay. The table shows that the percentages of Ca, Mg. and Na decreased during weathering, while in percentage of potassium increased. The increase in percentage of potassium (K) was the result of resistance of K minerals in proportion to the remaining mineral matter. The table also shows that the percentage of iron and aluminium increased during weathering and that the phosphorus persentage remined the same (16).

TABLE 3 — Chemical Compositon of Fresh and Weathered Amphibolite

Constituents	From Black Hills Fresh Rock %	Weathered Rock %
SiO_2	41.98	40.15
Al_2O_3	13.22	19.52
Fe_2O_3	2.22	11.97
FeO	15.64	3.95
CaO	10.91	2.73
MgO	5.45	2.09
Na_2O	1.23	0.45
K_2O	0.18	0.33
P_2O_5	0.36	0.36

(Thompson: Soils and Soil Fertility)

a) **Essential Elements :** For the normal growth of both higher plants and microorganisms, two conditions regarding the nutrients are vitally important. First, certain elements must be present and available for the use of the plant; and second, their concentration, especially in comparison with that of other essential nutrients, must be adjusted properly (10). The presence of too large an amount of one element may be as detrimental as an actual lack of this same constituent. Again the failure of the plant to utilize one element suitably may be due to an over -or under- supply of another.

Certain elements are, therefore, considered as especially desirable for successful crop growth. If they are lacking or improperly balanced, normal development does not occur. Fourteen such elements have been so recognized and their necessity can readily be demonstrated. They are listed in Table 4. (10).

TABLE 4 — Essential nutrient elements and their sources.

Relatively Large Amounts			Relatively Small Amounts	
Mostly from air and water		From soil solids	From soil solids	
C	N	Ca	Fe	Cu
H	P	Mg	Mn	Zn
O	K	S	Bo	

(Lycn, Buckman & Brady: The Nature and Properties of Soils, 1952.)

Of the eleven essential elements obtained from the soil by plants, six are used in relatively large quantites and consequently receive major attention. They are Nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. Besause they are used by plants in relatively large amounts they are sometimes designated for convenience as the primary elements (10).

Nitrogen, phosphorus, and potassium are artificially supplied to the soil. They are usually added as farm manure and especially as commercial fertilizers even in Forestry. Therefore, they are often called fertilizer elements. In the same way, calcium anda magnesium are commonly applied as lime and are called lime elements.

The other nutrient elements (iron, manganese, copper, zinc, and boron) are used by plants in very small amounts and as a consequence are sometimes called trace elements. Such a designation does not mean that they are less essential than the so-called primary elements. Trace elements are also very important for plant growth.

Soils vary greatly in chamical composition; but it might be possible to indicate the percentage rate within which the primary nutrients are ordinarily found when a number of surface soils is considered.

TABLE 5: Total Amoûnts of Organic Matter and Primary Nutrients Present in Temperate Region Mineral Surface Soils

Constituents	Ranges in Percentages that ordinarily may be expected	Representative Analysis Humid Region Soil		Arid Region Soil	
		%	Lb. to acre furrow-slice	%	Lb. to acre furrow-slice
Organic Matter	0.40 – 10.00	4.00	80,000	3.25	65,000
Nitrogen (N)	0.20— 0.50	0.15	3,000	0.12	2,400
Phosphoric Acid (P_2O_5)	0.02— 0.40	0.10	2,000	0.15	3,000
Potash (K_2O)	0.20— 4.00	2.00	40,000	2.40	48,000
Lime (Ca O)	0.10 5.00	0.60	12,000	1.50	30,000
Magnesia (Mo)	0.20— 0.50	0.50	10,000	1.00	20,000
Sulfur Oxide (So_3)	0.02— 0.50	0.10	2,000	0.20	4,000

(Lyon, Buchman and Brady, 1952).

As is shown, nitrogen and phosphorus are almost always present in comparatively small amounts in mineral soils. Moreover, a large proportion of these elements at any one time is held in combinations unavailable to plants (10). The organic matter percentage is usually critical because of its importance in keeping the soil loose, open, and high in available nutrients. Consequently, the phosphorus and nitrogen are often deficient.

In marked contrast to the phosphorus, potassium is usually present in large amounts. But availability is a problem.

Calcium and Magnesium are often less plentiful. Usully they are only deficient in areas where excessive water has dissolved them or where the parent material was low in them.

Sulfur is usually in low amounts (about the same as phosphorus) but is more readily available than phosphorus because sulfur compounds are more soluable than those of phosphorus.

From these brief explanations, it migh be stated that organic matter and nitrogen are especially critical because of importance and their low amount. Phosphorus is also a critical nutrient because of low amount present and low solubility of its compounds.

An examination of representative soil will reveal that in general the nutrient elements exist in two conditions: (1) complex and rather in-soluable forms and (2) simple compound usually soluble in the soil, water and rather readily available to higher plants.

The soluble forms of primary nutrients are easily removed in buried regions by continual leaching, soil organisms, and crops or other plants.

Organic matter is more than carbon, oxygen and hydrogen. It contains nitrogen, sulfur, phosphorus and other nurients. It is especially important as practically the only source of soil - Nitrogen, as important sources of phosphorus and sulfur (10).

IV. Fertility Reducing Agents in a Watershed

Several practices in the mismanagement of watersheds cause undesirable results and disastrous effects on the natural equilibrium of the environment. These may be summarized as follows:

A. Soil Erosion

Soil erosion is one of the most important results of mismanagement of the watershed which markedly reduces the soil fertility. The maintenance of soil fertility requires that erosion be kept at a rate low enough to permit soil formation to keep pace with erosion. Thus, the term «fertility erosion» has taken place in the classification of soil erosion. This type of erosion refers to **selective erosion.** The water erosion run off is either slow or light so that only the finer particles (silts and clays) are removed leaving the coarser, less fertile portion of the soil (15). The amount of top soil may be reduced materially by the removal of the coarser material over a period of years, but the most fertile portion of the soil is usually the first to be removed by wind and water.

Analysis of old cropped or eroded Willamette Valley soils in Oregon have shown definite reductions in plant nutrients and increase in soil acidity when compared with native sod land. The decreases in nitrogen, calcium, and sulphur were as much as 50 per cent. It is estimated that the soils Williamette Valley sustain a net annual loss of 20,000 tons of nitrogen and loss of potassium, sulphur, calcium, and magnesiums ranging from 2,500 to 106,000 tons annually (15).

The enormity of plant nutrient losses due to erosion is indicated by the amount of silt and nutrients carried in the water of the Tennessee River system. For example, on the assumption that this silt came entirely from the row crop, idle and other land subject to severe erosion. it has

been estimated that the loss from each acre of such land during 1939 would average 5.2 tons of silt, 84,6 pounds of CaO, 97.9 pounds of MgO, 212.2 pounds of K_2O, 13.0 pounds of P_2O_5, and 23.9 pounds of nitrogen. Calculated on the basis of the total acreage of the watershed, average acre - losses of the three bases, as oxides, carried in solution were 167.0 pounds of calcium, 31.7 pounds of magnesium, and 7.1 pound of potassium (15).

The amount of mineral nurients contained in the drainage waters of the Tennessee River Watershed varies with the nature of the stratum from which the waters flow. The water draining the limestone areas contains the greatest amount of total mineral matter and that from the sandstone areas least. However, the drainage waters from the sandstone areas contain more than twice as much potassium as the drainage waters from the limestone areas. The waters draining the high phosphatic soils of the bluegrass area contained the greatest amount of phosphorus. The greatest amount of nitrate - nitrogen was found in drainage waters containig the largest amount of soluble phosphorus, thus indicating the close relation between the soluble phosphorus and nitrate - nitrogen content (15).

TABLE 6: Amounts of nutrients carried in solution annually in the Ohio and Mississippi Rivers.

Element	Ohio River	Mississipi River
	tons	tons
P	17,129	62,188
Na	119,446	630,720
K	396,521	1,626,312
Ca	6,752,222	22,446,379
Mg	1,629,419	5,179,788
S	2,229,544	6,732,936

(Stallins; Soil Conservation, 1957)

Lipman and Conybear estimated that losses of nutrients by erosion exceeded the losses by cropping in the U. S. in 1930. Table 6 shows their estimates for the six macroelements obtained from the soil (16).

TABLE 7: Losses of Plant Nutrients by cropping and Erosion, 1930. In pounds per acre.

Losses	N	P	K	Ca	Mg	S
Removed in crops	25.1	3.8	17.3	6.0	2.8	2.8
Lost by erosion	24.2	10.6	141.1	152.0	73.0	6.1

(Thomson : Soils and Soil Fertility, 1952)

B. Fire

Burning as a means of changing vegetation, can have permanent or temporary effects; in many cases temporary changes caused by burning last a long time. Burning, which has been practiced on several vegetation types, in a watershed, has several effects on vegetation, runoff, soil erosion, soil, and the chemical composition of soils.

In this paper, the effect of burning on nutrient content of the soil will be taken into consideration only, and the other effects will be omitted.

Some burning experiments were carried out at North Fork experimental area, in San Joaquin Basin, California.

Colorimetric chemical tests were made in June 1935 of soil from 0 -to ½ inch and ½- to 2 inch depths of both the annually burned and undisturbed plots (13). These test showed a low concentration of nitrates and calcium in both soils. Soil extracts from the surface half inch soil depth of the undisturbed plots, however, contained approximately three parts per million (450 percent) more nitrates and about 10 percent more calcium than similar extracts from the soil of annually burned plots. The pH of the 0 - ½ inch soil depth of the undisturbed and annually burned plots averaged 6.7 and 7.0 respectively. Below the ½ inch depth there was no measurable difference in the nitrate and calcium content or pH of the two soils (13).

On the other hand, some other burning experiments were carried out on Mariposa soil series in Mendocino County. In these experiments, measurements of acidity, or pH of the soil, showed no significant differences between that of the burned and unburned areas, except in localized spots. The pH range was from 6.3 to 7.2 for the various burned and unburned soils examined (14).

Although much nitrogen is volatilized when vegetation is burned, the total soil nitrogen may not be greatly changed, since the decomposed roots, rather than top growth, apparently furnish the chief source of organic soil nitrogen (14).

Here the dominant vegetation consisted of greenleaf manzanita California scrub oak, and wedgeleaf ceanothus.

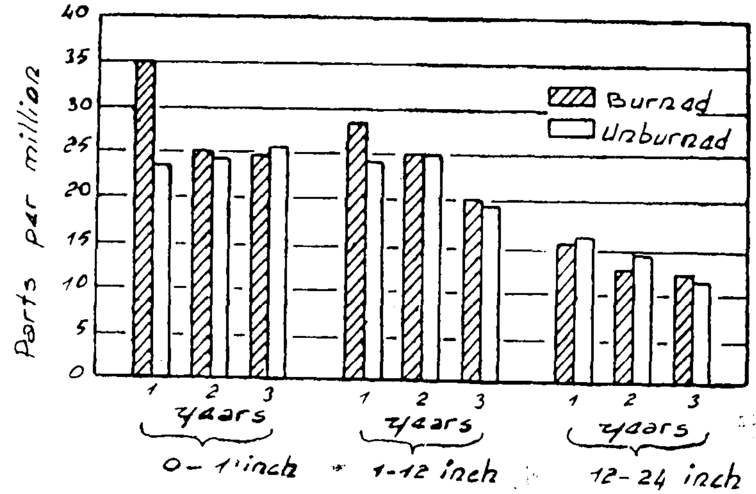

Figure 2: Nitrate nitrogen in field samples taken at three different soil dephts in the Mariposa silt loam of the mixed chaperral cover. (Sampson, A. B., 1944).

The figure above compares for three successive years, beginning in 1929, the trend of nitrate nitrogen at different depths in the soils of bruned and of similer adjoining unburned areas. The Mariposa soil series here studied was sampled in Mendocino County. Table 8 shows that the upper 1 inch of soil taken on the burned plots contained an average for all such samples (14).

TABLE 8: Nitrate nitrogen content of soil in a Chaparral Area Burned in 1928, and of a Similar Adjacent Unberned Area; Mariposa Soil Series, Mendocino County

Explainations	Soil reaction		p.p.m. NO_3 Nitrogen Content		% increase in NO_3 with Burning
	Burned	U.burned	Burned	U.burned	
FirstYear burning (1929) Sampling depth 0 inch - 1 inch	7.5	7.3	34.9	23.5	48.5
» » 1 inch - 6 inch	7.3	7.2	29.5	23.8	23.9
» » 6 inch-12 inch	7.2	7.2	26.5	25.7	3.1
» » 12 inch-24 inch	6.9	6.7	15.6	16.5	—5.5
Second Year Burning (1930) Sampling depth 0 inch - 1 inch	7.4	7.4	24.7	24.3	1.6
» » 1 inch-12 inch	7.3	7.3	24.9	25.2	– 1.1
» » 12 inch-24 inch	6.9	6.8	12.7	14.5	—12.4
Third Year After Burning (1939) Sampling depth 0 inch - 1 inch	7.4	7.5	24.7	25.7	—3.9
» » 1 inch-12 inch	7.4	7.3	20.4	19.7	3.6
» » 12 inch-24 inch	6.8	6.9	12.4	11.3	9.7

(Reference No. 14) (These figures are the average af different date of sampling)

48.5 percent increase in NO_3 content was found in the soil of burned plot after first year burning. On the other hand, the soil samples representing the lower soil depths gave nearly the same nitrate values for both the burned and unburned plots.

The nitrate values of samples taken from 0 to 1 inch in depth, dur-

ing the second and third years after the fire, were not significantly different in any burned and unburned area. At depths of 1 to 12 and 12 to 24 inches, the nitrate content was approximately the same on the burned and unburned plots the first year after the fire. Likewise, the second and third years after burning, no effect on the nitrogen content was discernible (14).

V. Soil Management and Restoration of the Fertility

The restoration of the soil fertility and productivity can be summarized briefly under two heads: (A) Soil Erosion Control, (B) Good Management of the Vegetation, and Fertilization.

A. Erosion Control

As has been stated above in Table 6, a considerable amount of plant nutrients have been lost by erosion. There is no doubt that the nutrient losses because of the erosion can be controlled or reduced by remedial measures. Erosion control means the maintanence of fertility.

B. Good Management of Vegetation and Fertilization

As mentioned above, an adequate vegetative cover in a watershed area is the only effective factor to prevent soil erosion, and loss of soil nutrients, and consequently to keep the fertility of the soil on an adequate level.

There are several environmental factors limiting plant growth and density of vegetation in a given area.

One of the causes of sparse vegetation in the Western U.S.A and similar arid lands is obviously the exceedingly dry summers which are usually without rain for five to six consecutive months. A very interesting study which will de presented below, was undertaken to determine whether the soil fertility is also o limiting factor in the development of the native vegetation.

The sparse vegetation and high erosion rate of the problem araes of the San Gabriel Mountains are cyclically related large areas of sparse vegetation occur within the 300 square miles of the mountainous part of the drainage (8).

The problem areas support a mixed vegatation of evergreen shrubs, collectivly termed chaparral. There is no seasonal herbaceous understory.

Many of these areas have been burned or altered in more than 30 years and apparently are suporting all the vegetation possible under existing environmental conditons. A field examination of root systems of the shruby species showed that in every instance the spread of roots exceeded the spread of tops. Thus, the soil mass below canopy openings is occupied by roots or adjoining shrubs (8).

Soils on the problem sites are shallow and undeveloped because of the continuous removal of the surface layer. The soil that is present is closely related in composition, therefore, to the underiying parent rocks. The principal parent rocks are anorthosite, which consist largely of plagioclase, diorite, and granitic (8).

The surface layer of soil is continually being removed from the slopes leaving a shallow residual soil mantle. This continuous removal of the surface layer also erodes away the plant nutrients, leaving a soil of low fertility. This study has shown that the fertility level is insufficient to support maximal growth of native plant species (8).

In the present study, the response of plants to soil fertilization was tested in both the laboratory and the field. In the laboratory experiments, soil fertility was varied by adding plant nutrients to each of three soils, and all other conditons for plant growth were held constant. Field trials based on the laboratory results were then conducted to determine whether soil nutritional deficiencies are overshadowed in nature by other environmental factors (8).

Soils used in the laboratory study were representative of the materials found on the exposed, rapidly eroding slopes. Samples of each soil, obtained at the 2 - 12 inch depth, were thoroughly mixed to assure uniformity in the test containers (8).

Five species of native shrubs and trees, all characteristic of the local chaparral, were tested for response to fertilization. The species were: Adenostoma fasciculatum H and A., Ceanothus crassifolius Torr., Pinus coulteri Con., Pseudotsuga macrocarpa Mayr., and Quercus chrysolepis Liebm. Uniform plant material for the experiment was obtained by growing, from seed, one to five plants in each of 75 replica pots of soil (8).

A five - factor factorial design was used in the fertilizer treatment, with each action and interaction replicated once. Nine nutritional elements were applied in five treatments. Nitrogen was given in the from of NH_4NO_3; phosphorus in $CaH_4(PO_4)_2H_2O$ potassium

in K Cl, and calcium in $Ca So_4 2 H_2 0$. Application was at the rate of 100 pounds of the element per acre. A composite minor element solution was also used. This was composed on a per - acre basis of Mn 10 pounds, Zn and Cu 5 pounds 2 inches below the soil surface and at two points equidistant from each other and the plant (8).

The individual species, depending on their rate of growth, were grown for periods varying from about 6 manths to 2 yars. The plants were harvested when they had attained an average size approximately 40 times that of the seedlings at the time the soil was fertilized (8).

TABLE 9: Weight of tops of native shrub and tree species on three San Gabriel Mountain soils, as influenced by nitrogen and phosphorus fertilization.

Plant Species and Soil Type	Control	N	P	NP	Least significant difference, 1 % level.
Adenostoma Fasciculatum					
Anorthosite	10.0	18.4	10.8	40.7	8.0
Lowe granodiorite	1.0	0.6	2.6	24.9	6.6
Wilson Diorite	6.7	25.3	8.4	38.7	7.6
Ceanothus carssifulius					
A.	32.9	67.7	46.6	65.0	15.0
L.	2.1	2.6	2.3	49.0	2.0
W.	20.3	47.7	28.3	66.0	21.0
Pinus Coulteri					
A.	11.9	23.5	11.6	26.8	2.7
L.	16.9	22.4	18.2	35.3	3.5
W.	13.4	23.5	13.2	24.0	5.0
Psedotsuga macrocarpa					
A.	22.4	40.6	27.2	52.9	11.0
L.	24.5	30.0	24.0	64.8	13.6
W.	15.7	33.6	20.9	61.6	10.2
Quercus chrysolepis					
A.	14.9	18.7	15.5	26.8	4.4
L.	16.4	29.6	19.2	26.8	7.0
W.	10.7	17.7	11.1	28.2	6.4

Other nutritional treatments including the microelement treatment produced only small and variable responses in plant growth (Table - 10). **(Reference No. 8).**

After harvesting separate statistical analyses were made of the dry weights on the tops and roots of each species in each soil to determine the growth response to the various fertilizer treatments.

Nitrogen alone and in combination with phosphorus produced a significant top growth response in all species. Most species showed slight response in growth to the additon of phosphorus alone, but only one species, C. crassifolius, produced a response large enough to be significant.

TABLE 10 : Weight of tops of five native tree and shrub species on three San Gabriel Mountain soils as influenced by potassium, calcium, and a mixture of microelements.

Plant species and soil types	K	Control	Ca	Control	Microelements	Control	Significant difference 5% level
	g.	g.	g.	g.	g.	g.	g.
Adenostoma fasciculatum							
Anorthosite	72.4	76.9	79.8	69.5	69.9	79.4	26.6
Lowe granodiorite	28.5	30.1	24.1	34.5	29.6	29.0	7.9
Wilson diorite	72.3	83.1	86.6	68.9	76.3	79.1	22.8
Ceanothus crassifolius							
A.	213.8	207.1	208.0	213.0	208.7	212.3	45.4
L.	41.2	54.9	49.2	46.9	41.9	54.2	31.2
W.	172.4	147.3	158.2	161.5	157.4	162.3	40.3
Pinus coulteri							
A.	78.0	74.8	72.2	80.5	79.0	73.8	9.2
L.	87.0	87.6	84.0	89.6	80.7	92.9	11.8
W.	74.7	56.8	65.9	65.6	62.7	68.9	13.7
Pseudtsuga macrocarpa							
A.	141.6	136.2	143.5	134.3	134.6	143.2	39.2
L.	107.6	137.2	121.4	123.4	101.5	143.3	39.1
W.	138.2	133.5	140.0	131.7	139.8	131.9	33.9
Quercus chrysolepis							
A.	73.3	64.1	67.4	70.0	61.4	75.9	13.9
L.	73.5	84.4	79.9	77.9	65.9	92.0	16.3
W.	62.5	56.0	63.5	55.0	50.8	67.8	14.0

(Reference No.8)

Addition of potassium caused a significant increase of growth in only one species (p. coulteri) and then only on Wilson diorite soil. Addition of calcium had no measurable effect on the growth of the plants testes Application of the minor element nutrient solution (B, Cu, Mn, Mo, and Zn) inhibited growth of Q. chrysolepsis on all three soils and of P. coulteri on Lowe granodiorite soil. The less concentrated solution of microelements usad on A. fasciculatum and C. crassifolius caused no growth response (8).

The nitrogen - phosphorus combination alone, of all fertilizer combinations used, caused a top - growth response significantly gerater than that caused by any elements applied singly (8).

The growth of each species was usually different in each of the three unfertilized soils. These differences were in some instances reduced by fertilization. The shrub species, A.fesciculatum and C. crassifolius, grew poorly without fertilization on Lowe granodiorite soil but well on the other two soils. Adding the N - P fertilizer reduced the growth differences of these plants on the three soils. The three species produced smaller differences in growth on the three soils. These growth differences indicate that the unfertilized soils are distinctly different in content of available plant nutrient (8).

Top to root ratio of species were affected by fertilization. Response of roots to fertilization followed the pattern of the top growth. The response, however, was of a lower magnitude than that of the tops and often insignificant. The greater response of the tops resulted in an increase of the top to root ratio for the plants grown with added nitrogen and nitrogen - phosphorus combinations (8).

On the other hand, corresponding experiments were carried out in the field. The significance of nutritional deficiencies could be overshadowed by the rainfall pattern and physical characteristics of the soil. Soil moisture is available for plant growth only for a limited period. The rainy season of southern California is confined to the winter months. May and October average less than 1 inch of rain a month, and no rain falls in the summer months. Furthermore, the amount of available water carried over into the summer months by the soil mantle is very low. The soils are shallow and because of their sandy nature have a low - water retention capacity. Thus, the lack of available moisture becomes a limiting factor for plant growth early in the summer (8).

Three species of native shrubs were included in the field tests.

Adenostoma fasciculatum, Arctostaphylos glandulosa, Ceanothus greggi have been tested in the field (8).

Each plot consisted of 16 subplots, four of which were untreated controls. The remaining subplots were treated with N (ammonium sulfate), P (surperphosphate) or a N-P combinaton. Fertilizer applications were made at the same level (100 poundswacrewelement) as in the laboratory (8).

The response to fertilization veried with the element applied and the four largest terminal shoots producede by the plant nearest the center of each treated subplot. Growth determinations were made in May for 3 consecutive years (8).

The response to fertilization veried with the element applied and the years since application. Significant increases in growth from the addition of N were obtained for A. fasciculatum and A. glandulosa on Lowe granadiorite soil and for A. fasciculatum and C. greggi anorthosite soil. The growth was sometimes greater in N - P treated subplots than in subplots that received N alone, but the increase was not significant. A decrease in the growth response is evident over the 3 - year period. No significant growth response was obtained for plants growing on Wilson diorite. P alone, and when applied with N failed to produce a significant increase in growth, even in the wettest year. This is in contrast to the laboratory results obtained under conditions of ample water. The lack of response to additional P in the field can hardly be due to P fixation by these sandy soils of low organic content. It is more probable that the available soil moisture becomes critical before all the available P is utilized (8).

Plants in the plots appeared to suffur no adverse physical effects from the increased growth produced by fertilization. They did not, for example, show increased susceptibility to drought or frost injury (8).

Consequently, from the laboratory study, it was determined that plant growth could be greatly stimulated by addition of nitrogen. An even greater stimulation was produced by adding N-P together (8).

The relationship between soil fertility and the natural supply of water was tested in the field. The results showed that nitrogen alone stimulated growth of the shrubs. N and P in combination failed to produce significant further increase in the shrub growh. From this it was concluded that lack of available moisture for plant growth became critical before all the naturally available phosphorus was used by the plants.

A study made on fertilization of the 30 - year - old Douglas Fir at Pack Forest, La Grande, Washington, also is interesting. Nitrogen was applied initially at three rate of 100 pounds per acre. Subsequent yearly additions have brought the total to 350 pound. Soil nitrogen content before fertilization was 0.12 % and Douglas Fir site class was a high V (volume) with a stocking of 3,500 trees per acre. Small quantities of phosphorus, potassium and lime were applied initially only (5).

The fartilizer treatment has resulted in the following growth modifications.

1. Accelerated diameter growth, particularly in the larger diameter classes.
2. Accelerated volume growth on both a tree and a stand basis. The fertilized stand had approàched Site III in periodic annual increment.
3. Development of natural competition and more rapid suppression of small trees on the plot (5).

VI. Summary

Soil fertility as a limiting factor for the plant growth and the density of vegetation is an important factor in a watershed. It varies by the influence of several factors, such as soil texture, stucture, organic matter, chemical composition of the parent rock, soil erosion and fire, etc.

But soil fertility can be recovered by preventing soil erosion, good management of the vegetation, and by fertilization.

VII. Conclusion

Experiment done on the nutrient losses by erosion have showed that it is tremedous amount. If the dense vegetative cover can be maintained in a watershed, the erosion will be markedly reduced and also, soil fertility level will be kept at an adequate level. However, in case of the high fertility level of a soil, erosion can be easily eliminated.

There are several recommendations to keep soil fertility at a good level.

1. Prevention of erosion,
2. Maintenance of an adequate vegatative cover,
3. Fertilization

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TÜRKÇE ÖZET

Havza Amenajmanında Toprak Verimliliği Problemi

I. Havza Amenajmanı ve Gayeleri

Havza Amenajmanı terimi son zamanlarda çok kullanılmaktadır. Kittredge'e göre «Havza Amenajmanı, bir drenaj havzasında erozyonu, dere akışlarını ve selleri kontrol altında bulundurmak ve kaliteli su istihsal etmek üzere o havzada yer alan tabiî kaynakların tanzimi ve idaresidir». Erozyon kontrolu, sediment hareketinin durdurulması veya sel zararlarının azaltılması gibi gayelerin tahakkuku için yangın veya başka sebeplerle tahrip görmemiş bir tabiî vejetasyon örtüsünün mevcudiyeti yeterli olmaktadır. Diğer taraftan, azami kullanılabilir kalitede su istihsalinin gaye olduğu yerlerde, istihsal edilecek suyun miktarı üzerinde mevcut tabiî vejestasyonun rolü son derece büyüktür.

Kittredge'e göre Havza Amenajmanı uğraşılarında dört safha vardır:

1. Birinci Safha: yağış havzası içerisindeki poroblemlerin yeri, mahiyeti ve ciddiyeti gibi hususları etüd eden «Problemleri Tanıma» safhasıdır.

2. İkinci Safha : erozyon ve selleri doğuran kötü şartların gerek vejetatif ve gerekse mühendislik tedbirleri ile ihya edilmesi gibi çalışmaları içine alan «Restorasyon» safhasıdır.

3. Üçüncü Safha : mevcut iyi şartların idamesini sağlama safhasıdır.

4. Dördüncü Safha : su verimini artıran uğraşıların başlatılması ile daha iyi şartların yaratılması safhasıdır.

Böylece, havza emenajmanının gayeleri özetlenirse bunlar; erozyonu zararsız bir seviyede tutmak, selleri doğuran her türlü akışın en iyi şekilde kontrolünü sağlamak ve kullanılabilir su verimini artırmaktır.

II. Bir Yağış Havzası Problemi Olarak Toprak Verimliliğinin Önemi

Toprak, bitkilerin üzerinde yetiştiği doğal bir ortamdır. Bu ortamın verimliliği ise bir havzadaki vejetasyon örtüsünün çeşitli rolleri bakımından yeterliliği üzerinde etkili bir faktördür.

Genellikle, «Prodüktivite» ile «verimlilik» (fertility) terimleri üzerinde tarif bakımından bütün bilim adamları tarafından kabul edilmiş bir beraberlik yoktur (9). Bazılarına göre, toprakta bitkiler için yeterli besin elementlerinin, su ve organik bileşimlerin var olması ve bitki hayatını tehdit eden zehirli maddelerin bulunmaması halinde bir toprağın hem verimli, hem de prodüktiv olacağı kabul edilmişken, diğer bir görüşe göre böyle bir toprak kurak bir bölgede bulunsa idi yetişme muhitinde doğal olarak mevcut olmayan suyun (sulama ile) sağlanması halinde prodüktiv hale getirilebileceği aşikârdır. Bu itibarla bu tezi savunanlara göre verimlilik daha çok toprağın besin elementleri kapsamı ve zehirli bileşimlerden yoksun bulunması koşullarına bağlanmaktadır. Bu görüşe göre, sıcaklık, ışık, yağış ve drenaj gibi yetişme ortamı koşulları ihmal edilmektedir. Bununla beraber, yaygın bir terim olarak verimlilik ve prodüktivite terimleri eşdeğer olarak ayni manada kullanılmaktadır (9). Bu yazıda ise «verimlilik» sadece toprak özellikleri ile ilgili bir anlamda kullanılmaktadır. O halde toprağın kimyasal ve fiziksel özellikleri, ve meselâ derinlik, tekstür ve strüktür gibi su depolama kapasitesini etkileyen faktörler, erozyona dayanıklılık gibi nitelikler havza amenajmanında toprak verimliliği ile ilgili hususlardır. Nitekim Lyon, Buchman ve Bready'in ifa ettikleri gibi, erozyon kontrolünde son derece önemli olduğu halde en çok ihmal edilmiş olan tedbir, toprak verimliliği ve prodüktivitenin devamlılığını sağlamaktır.

III. Toprak Verimliliği ve Prodüktivitesini Etkiliyen Faktörler

A. Toprakların Fiziksel Özellikleri

Birçok fiziksel özellikler toprakların verim kapasiteleri üzerinde etkili olmaktadır. Meselâ, havalanma ve toprak suyu ilişkileri, kök derinliği ve fiziksel toprak özellikleri tarafından büyük ölçüde etkilenir. Bu özellikler başlıca tekstür, strüktür, renk, porosite ve su tutma kapasiteleri olarak kısaca bu yazıda üzerinde durulmuştur.

Tekstür, toprak danecikler inin büyüklükleri ile ilgili bir özelliktir. Kum, toz ve kil fraksiyonlarının çeşitli oranlardaki karışımı, farklı teks-

türleri meydana getirir. Kil fraksiyonu ve humus genellikle kolloidal özellikler taşır ve fiziksel, kimyasal ve biyolojik birçok olaylar bu fraksiyonu teşkil eden canlı veya cansız bir takım temel unsurların mevcudiyetine bağlıdır. Bilindiği gibi kil mineralleri toprakta besin elementlerini kapsayan bir komponent olarak büyük önem taşırlar. İklim ve diğer oluşan koşullarına göre kil mineralleri üç genel grupta toplanır : (1) Kaolinit, (2) Montmorillonit, (3) Illit (Hidratlanmış mika). Bu kil minerallerinden Montmorillonit en yüksek mübadele kapasitesine (80 - 100 m. e./100 g.) sahip olduğu halde, diğeri; illit (20 - 40 m. e./100 g.) ve kaolinit (3 - 15 m. e./100 g.) daha düşük değerler gösterirler.

Diğer taraftan organik madde de toprak özelliklerini çeşitli şekillerde etkiler. Bunları aşağıdaki şekilde sıralamak mümkündür:

1. Toprak rengini etkiler.... kahverengi - siyah.
2. Fiziksel özellikleri etkiler.
   a. Granular strüktür gelişimine sebep olur.
   b. Plastiklik, kohezyon gibi nitelikleri etkiler.
3. Mübadele kapasitesini artırır.
4. Agregat stabilizasyonunu yani agregatların dayanıklılığını artırır.
5. Toprakların infiltrasyon kapasitesini artırır. Yüzeysel akışı ve dolayısıyle erozyonu azaltır.
6. Toprağa kabil-i istifade besin elementleri sağlar.
   a. Kolaylıkla alınabilen katyonlara sahiptir.
   b. Azot, fosfor ve kükürt gibi elementler organik formlar halinde bulunurlar.
   c. Minerallerden besin elementlerinin ekstraksiyonu, asit humus vasıtasiyle alır.

Topraktaki organik maddenin miktarını etkileyen en önemli faktörler ise vejetasyon, topografya, ana materyal, iklim ve zamandır. Topraktaki organik madde daha ziyade bitki artıkları ile sağlanır. Bir mer'adaki otların kök sistemi daha ziyade toprak yüzeyine yakın bir ortamda yayılır ve kök konsantrasyonu derinlere doğru azalır. Buna bağlı olarak organik madde de toprak derinliği ile tedrici olarak azalır. Diğer taraftan ağaç kökleri yüzeyde değil daha ziyade derinlere doğru dağılmış durumdadır. Böylece bir ormanda, toprak organik maddesinin en büyük kısmı yaprak ve ibre dökümü ile sağlandığı cihetle, organik madde daha ziyade yüzeyde birikme eğilimindedir.

Bu izahlardan da anlaşılacağı üzere organik maddenin miktarı vejetasyon tipi tarafından etkilenmektedir. Dolayısiyle toprak verimliliğinde vejetasyon indirekt olarak rol oynamaktadır.

Bir ormanda besin elementlerinin takip ettiği devre içerisinde (nutrional cycle) ölü örtünün önemi herkez tarafından kabul edilen bir husustur. Ölü örtünün çeşitli kısımlarında depo edilmiş bulunan besin elementleri, bir orman ekosistemi içersinde toprak verimliliğinin devamlılığı ile çok sıkı bir şekilde ilgilidir. Nitekim Romell ve Heiberg (1931), Romell (1935) ve Cole ve Gessel (1963) tarafından yapılan araştırmalar göstermiştir ki, ölü örtüye bağlı olarak bulunan elementlerin serbest hale gelmesi ve besin devresi içindeki hareketi Silvikültürel muamelelerle büyük ölçüde etkilenmektedir. Bu bakımdan ormancıların bu besin deposunu daima dikkate almaları ve ormancılık uğraşılarını ona göre tanzim etmeleri gerekir. Orman ölü örtüsü ayni zamanda toprak erozyonunda, orman hidrolojisinde, toprak biyolojisinde de çok etkili olmaktadır. Ancak bütün bu ilişkiler tam olarak aydınlanmış değildir (4). Balcı'nın (2) belirtiğine göre (Tablo-2) bir Pseudatsuga ormanında Mor tipi ölü örtü (157.9 ton/Ha), duff-Mull tipi ölü örtüden (103.4 ton/Ha) daha fazladır. Bu ölü örtülerde büyük miktarlarda N,P, K ve C depo edilmiş bulunmaktadır. Nitekim, mor (2,040 kg./Ha) ve duff-mull (1,393kg./Ha) ölü örtülerde mevcut bulunan azot, bir meşcerenin yıllık ihtiyacını çok aşmakta dır (2). Bu itibarla, bir orman ekosisteminde besin elementleri devresinde ölü örtünün önemi çok büyük olup, mutlaka öncelikle gözönünde tutulması gerekir.

Ayni şekilde toprak strüktürü bilhassa ağır tekstürlü topraklarda mahsül istihsalini ve vejetatif büyümeyi sınırlayıcı bir toprak özelliğidir. Toprak strüktürü ayni zamanda toprak erozyonunu ve toprak verimliliğı de etkileyen bir faktördür.

B. Toprakların Kimyasal Özellikleri :

Toprak, muhtelif büyüklükte ve ayrışma safhasında taş ve mineralleri kapsar. Taş ve minerallerin tecezzi etmeleri ile büyüklükleri değişir, kimyasal ayrışmaları ile ise kimyasal bileşimlerinde değişmeler olur. Bu kimyasal ayrışım sonunda ise bitki hayatı için gerekli olan iyonlar serbest kalmış olurlar.

Mineral ve taşların tecezzi etmeleri büyük ölçüde farklar gösterir. Nitekim Potasyumlu mineraller genellikle kalsiyum kapsayan minerallere nazaran daha yavaş tecezzi eder. Kuvars ise mineraller içerisinde fiziksel ayrışmaya karşı en dayanıklı olanıdır.

Mineraller ve taşların ayrışmaları sonucunda serbest kalan maddelerden kolay eriyebilenler yıkanıp giderlerken, daha dayanıklı olanlar da birikirler. Nitekim ayrışma mahsüllerinden silisyum, demir ve aliminyumun oksitleri yıkanmaya en çok dayanıklı olduklarından, ayrışma sırasında daha çok birikirler. Tablo 3. bu gerçeği göstermektedir. Bütün bunlardan anlaşılmaktadır ki taş ve minerallerin terkibi ve ayrışma kabiliyeti toprak verimliliğine tesir eden iyonların ve bileşimlerin miktar ve cinsi üzerinde etkili olmaktadır.

Bitkilerin ve mikro organizmaların normal bir büyüme yapabilmeleri için besin ihtiyaçları bakımından iki şartın mevcut olması lâzımdır. Birincisi muayyen bazı elementlerin mevcut olması, ikincisi ise bu elementlerin konsantrasyonlarının arzu edilen seviyede birbirleri ile ahenkli bir şekilde olmasıdır. Nitekim bir besin elementinin çok fazla olması halinde bitkiye yaptığı zarar, hiç bulunmaması halindeki kadar olabilir. Bu itibarladır ki bazı elementler bitkiler için özellikle lüzumludur. Bu temel elementler ondört tane olup Tablo: 4 te görülmektedir. Bunlardan altı tanesi yani azot, fosfor, potasyum, kalsiyum ve sülfür topraktan alınır ve büyük miktarlarda kullanılır. Diğer taraftan demir, manganez, bakır, çinko ve boron bitkiler tarafından çok az miktarlarda kullanılır fakat bitki büyümesi için esas elementlerdendir.

Nemli ve kurak iklim topraklarının kapsadıkları besin elementleri miktarları ve yüzde degerleri Tablo: 5 te verilmiştir. Buradan görüleceği gibi, azot ve fosfor mineral toprak içinde nisbeten az bulunur. Organik madde ise verimlilik üzerinde etkili olduğu ve toprağa birçok iyi fiziksel özellikler sağladığı için önem kazanır. Bilhassa bitkilerin «Kabil-i istifade» elementlere olan ihtiyacı bakımından organik madde mühimdir. Bu itibarla organik maddenin bu öneminden ötürü toprakta yeteri kadar bulunmaması ekseriye azot ve fosfor noksanlığı sonucunu doğurur. Fosforun aksine potasyum bol bulunmasına rağmen faydalınılabilir (avaiability) formda olmaması bir problem teşkil eder.

Kalsiyum ve mağnezyum da çok fazla bulunmamakla beraber ancak çok nemli bölgelerde yıkanıp gitmeleri veya ana-materyalin bünyesinde esasen bulunmaması veya az olması sebebiyle toprakta noksan olabilirler. Sülfür ise fosfor gibi az bulunmakla beraber fosfora nazaran daha kolay eriyik haline gelebilme özelliği dolayısiyle daha çok kabil-i istifade (faydalanılabilir) halde bulunur.

IV. Bir Yağış Havzasında Toprak Verimliliğini Düşüren Faktörler

Yağış havzalarındaki yanlış uygulamalar ve kötü faydalanmalar yetişme ortamındaki doğal dengeyi ters yönde etkileyen ve zararlı sonuçlar doğuran niteliktedir. Aşağıda bu faktörler sıralanmıştır.

A. Toprak Erozyonu:

Toprak verimliliğini büyük ölçüde azaltan toprak erozyonu bir yağış havzasındaki kötü ve yanlış idare ve uygulamaların en önemli bir sonucudur. Toprak erozyonu o şekilde kontrol edilmeli ve düşük bir düzeyde tutulmalıdır ki, erozyonla kaybolan miktarla toprak teşekkülü ile kazanılan arasında bir denge meydana gelsin ve böylece de toprak verimliliğinin devamlılığı sağlansın. Nitekim erozyon sınıflamasında «verimlilik erozyonu» deyimi kullanılmaktadır ki bu terim **ayıklayıcı erozyon** veya **tasnif edici erozyon** yani toz ve kil gibi toprakların ince fraksiyonunun yüzeysel akışla yıkanarak yitirilmesi ve geride daha az verimli olan kaba fraksiyonların kalması anlamına gelmektedir. Böylece toprakların en verimli kısımları su ve rüzgâr erozyonu ile kaybolmaktadır.

Oregon (A.B.D.) eyaletinin Willamette vadisindeki çok kullanılmış ve erozyona maruz kalmış topraklarında yapılan analizler göstermiştir ki, tabiî olarak yetişmiş otlarla kaplı mer'a topraklarına nazaran, tarım yapılmış topraklarda besin elementleri miktarında kesin bir azalma, toprak asiditesinde ise artma meydana gelmiştir. Azot, kalsiyum ve sülfür miktarlarındaki azalma % 50 kadar olmuştur. Bu çalışmaya göre Willamatte vadisi topraklarında yıllık azot kaybı 20.000 ton, potasyum, sülfür, kalsiyum ve mağnezyumun yıllık kaybı ise 2500 den 106000 tona kadar ulaşmaktadır.

Ayni şekilde Tennessee nehri drenaj sisteminde şiddetli erozyon sebebiyle nehir sularında 1939 yılı içerisinde hektardan 13 ton toz fraksiyonu, 94,8 kg. CaO, 109.8 kg. MgO, 237.9 kg. K_2O, 14.6 kg. P_2O_5 ve 26,7 kg. de azot yıkanıp gitmiştir.

Yine Tennesse nehri yağış havzasında drenaj sularının kapsadığı besin elementlerinin cinsi ve miktarı, bu suların geçtikleri jeolojik ortama bağlıdır. Nitekim kalkerli bir bölgenin suları total elementler bakımından en yüksek miktarlara sahip olduğu halde, kumtaşı ana taşının bulunduğu bölgenin suları en küçük miktarı kapsamaktadır. Buna mukabil kumtaşı drenaj suları, kalkerli arazi sularının iki misli potasyum kapsamaktadır. Ayni şekilde fosfatlı toprakların sularında büyük miktarda fosfor bulunmaktadır. Ayni sularda nitrat - azotunun da fazlaca bulunması eriyebilen fosfor miktarı ile bu nitrat azotu arasında yakın bir ilişki bulunduğunu göstermektedir.

B. Yangın:

Bir yağış havzasında yangının veya yakmanın, vejetasyon, yüzeysel akış ve dere akışı, toprak erozyonu, toprak ve toprağın kimyasal üzerinde çok çeşitli etkileri vardır. Ancak burada sadece toprağın besin muhtevasına olan etkisi incelenecektir.

Kalifornia'daki North Fork araştırma sahasında yapılan yakma denemelerinde, yangının uygulanmış olduğu parsellerle kontrol parsellerinde nitrat ve kalsiyum konsantrasyonları düşük bulunmuştur. Diğer taraftan yüzeyden itibaren 1 - 1.5 cm. kalınlıktaki toprağa ait ekstraktlardan kontrol parseline ait olanlarda, yangın görmüş toprağa nazaran % 450 daha çok nitrat ve % 10 daha fazla kalsiyum bulunmuştur. Toprağın ilk santimetrelerine ait pH değerleri ise 6.7 kontrol parselinde, 7.0 ise yanmış parseldekindedir. 4 - 5 cm. derinliğe ait pH. değerlerinde ise fark yoktur. Diğer taraftan Mendocino County de yapılan bir yakma denemesinde ise pH bakımından yanmış ve yanmamış topraklar arasında hiçbir fark bulunamamıştır.

Yine yapılan denemeler göstermiştir ki yanma ile topraktaki NO_3 miktarında yanmamış toprağa nazaran % 48.5 bir artış husule gelmiştir (Tablo. 8).

V. Toprak Amenajmanı ve Toprak Verimliliğinin (Restorasyonu) İadesi

A. Erozyon Kontrolü

Erozyonla toprakların taşınması sonucu büyük ölçüde besin maddelerinin taşındığı ve erozyonun toprak verimliliğini azaltan olumsuz etkileri olduğu yukarda ifade edilmiştir. Bu itibarla, erozyon kontrolu toprak verimliliğinin korunması ve devamlılığı bakımından alınacak tedbirlerin başında gelir.

B. İyi Bir Vejetasyon İdare ve İşletmeciliği

Bir yağış havzasında erozyonu önlemenin ve dolayısiyle topraktaki besin elementlerinin kaybını azaltmanın ve toprak verimliliğini arzu edilir bir düzeyde tutmanın yegane yolu, o havzada yeterli bir vejetasyon örtüsünün varlığını sağlamaktır.

Ancak, doğal olarak yetişen vejetasyon örtüsünün büyümesi ve sıklığını etkileyen çeşitli yetişme ortamı koşullarından bilhassa kurak yazlar ve su noksanlığı önemli bir yer işgal eder. Bu gibi kurak yerlerde, ayrıca toprak verimliliğinin vejestasyonu etkileyici ve sınırlayıcı bir etken olup olmadığı sorunu, üzerinde durulmaya değer.

Bu yönde yapılmış bazı araştırmalarla elde edilen sonuçlar ilgi çekicidir. Nitekim Amerika'da San Gabriel Mountains daki araştırma sahalarında, bilhassa büyük ölçüde erozyona uğramış bulunan ve seyrek bir çalı vejetasyonunu kapsayan problem alanları alınmıştır. Bu alanlar 30 seneden beri çeşitli yangın ve değişimlere maruz kalmıştır. Vejetasyonda kök gelişmesi tepe gelişmesinden daha fazladır. Üst toprağın erozyonla taşınması sebebiyle toprak sığdır. Böylece üst topraktaki bitki besin elementleri de taşınmakta ve toprak düşük bir verimliliğe sahip bulunmaktadır.

Laboratuvar ve arazide bu topraklar üzerinde gübreleme denemeleri yapılmıştır. Laboratuvarda diğer koşullar sabit tutulmak suretiyle topraklara gübre ilâve edilmiştir.

Erozyona maruz kalmış bu alanların üst topraklarından (5 - 60 cm) alınan toprak örneklerinde beş chaparral (Maki vejetasyonuna benzer bir çalı formasyonu) türü yetiştirilmiş ve dokuz besin elementi Azot ($NH_4 NO_3$), Fosfor ($CaH_4 (PO_4)_2 H_2O$), Potasyum (KCI ve Kalsiyum ($CaSO_4 2.H_2O$) gübreleri hektara 112.1 kg. miktarında uygulanmıştır. Ayrica diğer tali elementler de verilmiştir. 6 - 24 ay sonra yetişen bitkiler kesilmiş ve gövde ve tepe kısmı ile kök kısımları tartılmak suretiyle gübreleme sonucu büyümede meydana gelen değişmeler izlenmiştir.

Bütün türlerde azot, kendi başına ve fosforla karışık olarak istatistiki bakımdan iyi sonuç vermiştir. Bitkilerin ekseriyeti fosforun yalnız olarak verilmesine karşı bir büyüme reaksiyonu yapmamıştır. Potasyum sadece bir türde etkide bulunmuş, kalsiyum ise deneme bitkilerinde hiçbir önemli etkide bulunmamıştır.

Gövde - kök oranı gübreleme ile etkilenmiştir. Bilhassa Azot ve Azot-Fosfor kombinasyonu tepe büyümesini artırmıştır.

Arazide yapılan denemelerde ise; besin maddeleri noksanlığının önemi, yağışların dağılışı ve toprakların fiziksel özellikleri tarafından gölgelenmektedir. Diğer bir deyimle adı geçen iki husus, besin maddeleri noksanlığından daha önemli bir yer almaktadır. Nitekim Güney California'da yağışlar daha çok kış aylarında düşmekte yaz ayları kurak geçmektedir. Toprak sığ ve tekstür kumlu olduğu için de düşük bir retensiyon kapasitesi bitki büyümesini sınırlayıcı olmaktadır.

Denemelerde Adenostoma fesciculatum, Arctostaphylos glandulosa ve Ceanothus greggi çalı türleri teste tâbi tutulmuştur. 16 adet parsel alınmış ve bunlar arasında 4 tanesi kontrol için bir işlem görmemiştir. Geriye kalan 12 parselden N (Amonyum sülfat), P (Süper fosfat) veya

N - P (azot - fosfor) kombinosyonu kullanılmıştır. Verilen gübrenin miktarı (112.1 kg/ha/element) tir. Yıllık büyüme orta sürgünlerin kuru ağırlığı şeklinde tespit edilmiştir. Gübrelemenin büyüme üzerindeki etkileri verilen elementin cinsine ve uygulama yılına göre değişik olmuştur. Nitekim, granadiorit toprakları üzerindeki A. fasciculatum ve A. glandulosa ile anarthosit toprağı üzerindeki A. fasciculatum ve C. greggi de meydana gelen büyüme, N gübrelemesi sonucu önemli derecede artmıştır. Bazı hallerde N - P kombinasyonu sadece N uygulamasına nazaran büyümede daha fazla bir artış meydana getirmişsede bu istatistiki bakımdan önemli olmamıştır. Diğer taraftan diorit toprakları üzerindeki bitkilerden ise gübrelemenin büyüme üzerinde hiçbir etkisi olmamıştır. En yağışlı yılda bile, P veya P - N kombinasyonu gübrelemesi büyümede hiçbir artış yaratmamıştır. Bu sonuç ile lablratuvarda uygun sulama şartları altında elde edilen gübreleme sonuçları arasında bir aykırılık vardır. Arazideki bu olumsuz sonuç düşük organik madde muhtevasına sahip olan kum toprağındaki bir P - fiksasyonu sorunundan ziyade kabil-i istifade fosforun tamamen kullanılmasından önce, kabili istifade suyun kritik bir sınıra erişmiş olması ihtmalinden ileri gelmiştir.

Netice olarak denebilir ki, laboratuvar etüdlerine göre bitki büyümesi N gübresi ile büyük ölçüde artabilmekte, ve bu artış N-P kombinasyonu gübrenin verilmesiyle daha da büyük olmaktadır.

Diğer taraftan Washington Eyaletinde Pack Forest'de 30 yaşındaki Psendotsuga'lara verilen azot, fosfor ve potasyum gübreleri aşağıdaki sonuçları vermiştir:

1. Bilhassa kalın çaplı ağaçlardaki çap büyümesi hızlanmıştır.
2. Ağaç ve meşcere hacminde artma olmuştur.
3. Meşcerede tabiî rekabeti geliştirmiş ve küçük ağaçların daha çabuk baskı altına girmesini sağlamıştır.