

The methods of measuring productivity



1. Definition:

Productivity refers to rate at which energy is accumulated by green plant in unit time in the form of organic substance that can be used as food.

2. Types of Productivity:

Productivity involves four successive

Primary productivity

Gross primary production

Net Primary Production

2. 1 Primary Productivity:

The rate at which radiant energy is stored by photosynthetic activity of green plants and algae in the form of organic substance is termed as primary productivity, because it is the first and most basic form of energy stored in the ecosystem.

2. 2 Gross Primary Production (GPP)

The total photosynthesis that is all of the sun's energy that is assimilated is called gross primary production or GPP. It includes the organic matter used up in respiration during the measurement period. It is also called total assimilation.

2. 3 Net Primary Production (NPP)

Energy remaining after respiration and stored as organic matter during the period of measurement is known as net primary production. It is also called

apparent photosynthesis. Net production is the energy available to the heterotrophic components of the ecosystem.

A portion of net primary production is used by plants for growth the build up components such as stem and leave and a portion go to storage organic compound stored for future growth and other functions.

The flow of energy during primary production can be expressed by the formula.

Gross primary production (GPP) = net primary production (NPP) + respiration (R)

3. Factors influencing productivity:

The production efficiency of plants depends upon factors such as light intensity the quantum efficiency of light the leaf arrangement on the plants the leaf area index and the type the plant whether C-3 or C-4. The environment factors that help promote net productivity include warm temperature greater rainfall moving water that carries additional nutrients in natural ecosystem and irrigation application of fertilizers and control of pest in agricultural crops. Swamps and marshes present at the interface of land and water have net productivity ranging from 900 to 3300 g/m²/yr.

4. Methods of Measuring Productivity:

Productivity is usually measured as the rate at which energy or biomass is produced per unit area per unit time. This rate is expressed in such terms as kilocalories per square per year (kcal/m²/yr) a measured or energy or germs

per square meter per year a measure of biomass. Various techniques used to estimate primary productivity are

Light and Dark Bottle Method

Radioactive Tracer Method

Chlorophyll Concentration

Carbon Dioxide Flux

Harvest Analysis

Dimension Analysis

4. 1 Light and Dark Bottle Method:

This method is employed to measure primary productivity in an aquatic ecosystem such as a pond. It is based upon the assumption that the amount of oxygen produced is proportional to gross production because one molecule of oxygen is produced for each atom of carbon fixed. Samples of water from different depths are placed in paired bottles. One of the paired bottles is covered with black tape or aluminium foil to exclude light and other is kept clear to admit light and allow photosynthesis. The oxygen concentration of the bottles is determined by Winkles method. The bottles are suspended to the same depth from where samples were collected with the help of string. After 24 hours the bottles are removed their oxygen concentration is determined and compared with the concentration at the beginning. The decline of oxygen in the dark bottle indicates the amount of respiration by producers and consumers where the oxygen change in the

light bottle reflects the net result of oxygen consumed by respiration and oxygen produced. Adding respiration and production together or subtracting final oxygen concentration in the dark bottle from that in the light bottles give an estimate of gross productivity for 24 hours. This method has its problems. Some of the respiration attributed to phytoplankton may be bacterial. The phytoplankton population may increase in the bottle during the experimental time but not in dark bottle. Also the procedure is based on the assumption that respiration in the dark is the same as in the light.

4. 2 Radioactive Tracer Method:

It is one of the most useful and sensitive method useful to estimate primary productivity in an aquatic ecosystem especially in lakes and oceans. It is based upon measurement of $^{14}\text{CO}_2$ uptake. The method involves addition of radioactive carbon as carbonate to a sample of water in clear and unstable carbon are assimilated into carbohydrates and become part of the protoplasm of phytoplankton. The plankton material is removed from the water washed dried and place in a counting chamber to determine the level of radioactivity. The radioactive counts are used to calculate the amount of carbon dioxide fix in photosynthesis using the photosynthetic equation. The estimate is based on the assumption that of radioactive carbon is proportional to that of stable carbon. However in practice these may not be proportional therefore a correction factor for ^{14}C adsorption in dark bottle is required.

The technique has its deficiencies. It does not discriminate between respiration of phytoplankton and bacteria the uptake and release of ^{14}C by

bacteria and zooplankton and the abilities of different species of phytoplankton to use available light.

4.3 Chlorophyll Concentration:

This method is based upon estimation of producer from chlorophyll concentration and light intensity through the water column. The technique evolved from the discovery by plant physiologist that a close relationship exists between chlorophyll concentration and photosynthesis at any given light intensity. If the assimilation ratio and the available light are known gross production can be estimated by the extracting pigments and then measuring the chlorophyll concentration with a spectrophotometer. The method was first to used to estimate primary productivity in large water bodies such as sea but later applied to terrestrial ecosystem as well as. This method involves the determination of chlorophyll contents of phytoplankton in a given volume of water. Because all plant need chlorophyll to carry on photosynthesis the amount of chlorophyll in a given amount of water is a direct measure of the total biomass or standing crop of phytoplankton it contains. The chlorophyll is extracted chemically and the amount of chlorophyll is measured. The deeper the colour the greater is the concentration of the chlorophyll and therefore phytoplankton biomass.

The technique has a problem that chlorophyll concentration varies with phytoplankton species and even within the cells of species. Further extraction technique may alter the chlorophyll.

4. 4 Carbon Dioxide Flux:

It is one of the most useful methods for estimating primary productivity in terrestrial ecosystems. It helps measuring both gross and net primary production. It involves measurement of the uptake of carbon dioxide in photosynthesis and its release in respiration. In this method a sample of community which may be twig and its leaves a segment of a tree stem the ground cover and soil surface or even a portion of the total community such as an on site sample of grassland is enclosed in a clear plastic tent. Air is drawn through the enclosure and the carbon dioxide concentration in incoming air and outgoing air is measured with an infrared gas analyzer or by absorption on a KOH column. The assumption is that any carbon dioxide removed from the incoming air during the day has been incorporated into organic matter. Therefore the quantity of carbon dioxide in the enclosure is equivalent to photosynthesis minus respiration. A similar sample may be enclosed in dark enclosure. The amount of carbon dioxide is produced in the dark bag is a measure of respiration when photosynthesis stops. The quantity of carbon in the light and dark enclosure added together estimates gross production.

4. 5 Harvest Analysis (Standing Crop Method):

Harvest method is widely used to estimate in terrestrial ecosystem. It is most useful for estimating the production of cultivated land range and communities of annual plants where production starts from zero at seedling or planting time becomes maximum at harvest and is subject to minimal use by consumers.

The technique involves removing vegetation at periodic intervals and drying the samples to a constant weight. To obtain an accurate estimate the production of plant biomass must be sampled throughout the growing season and the contribution of each species must be determined. Different species of plants reach their peak production at different times during the growing season. The difference in standing crop biomass between harvest periods expressed as grams per square meter per unit time provides an estimate of net primary productivity. Caloric value of the material can be determined through use of a calorimeter and biomass can be converted to calories. Net primary productivity is then expressed as kilocalories per square meter per year.

Harvest method provides information about above ground productivity usually because low ground productivity requires the samples of root biomass which is difficult at best. Although the roots of some annual and crops plant may be removed from the soil the task become more difficult with grass and herbaceous species and even more so with forest trees.

4. 6. Dimension Analysis:

Because plant of different age, size and species make up the forest community modified harvest technique called dimension analysis is used by ecologist. This methods help to estimate standing crop and productivity from less intensive sampling. Dimension analysis involves the measurement of light, diameter or breast height and diameter growth and age is determined by growth ring analysis. Total weight both fresh and dry of leaves and branches as well as the weight of also determined. Often the roots are excavated and weighted. Similarly biomass of ground vegetation litter fall is

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also determined. Net annual production of wood, bark, leaves, twigs, roots and flower is calculated. All these information are used to calculate production of trees and other vegetation in a sample unit. After dimension analysis the standing crop can be predicated by using data such as (diameter) $2 \times \text{height} \times$ and annual productivity by measuring current wood growth.

5. Summary:

Plants use part of total energy fixed by photosynthesis as maintenance energy. The remainder is used for new plant biomass and reproduction and is food for herbivores. The amount distribution and the rate of turnover of biomass determine many important characteristics of the community physiognomy diversity of herbivores and activity of decomposers. These relationships are constrained by the efficiency which plant absorb light incorporate absorbed energy into photosynthate and convert photosynthate into biomass. Productivity is measured by several means. (a) Determining the rate of photosynthesis and respiration (b) estimating changes in biomass over time, (c) Correlating biomass to an easily measured variable to estimate standing crop, (d) Use of computer models to determine productivity over broad spatial scales and predict response to changing environmental conditions. Productivity in terrestrial ecosystem is influenced by numerous factors: carbon dioxide, light, temperature, moisture, nutrients, and soil texture. The most productive ecosystems are those with optimal levels of such factors, ultimately to maximize photosynthesis. These factors exert their influence simultaneously and interactively often doing so in a non equilibrium manner.