Primary Productivity

The energy entering ecosystems is fixed by producers in photosynthesis. The rate of photosynthesis is dependent on factors such as temperature and the amount of light, water, and nutrients. The total energy fixed by a plant through photosynthesis is referred to as the **gross primary production (GPP)** and is usually expressed as Jm^{-2} (or kJm^{-2}), or as gm^{-2}. However, a portion of this energy is required by the plant for respiration. Subtracting respiration from GPP gives the **net primary production (NPP)**. The **rate** of biomass production, or **net primary productivity**, is the biomass produced per area per unit time.

Measuring Productivity

Primary productivity of an ecosystem depends on a number of interrelated factors (light intensity, nutrients, temperature, water, and mineral supplies), making its calculation extremely difficult. Globally, the least productive ecosystems are those that are limited by heat energy and water. The most productive ecosystems are systems with high temperatures, plenty of water, and non-limiting supplies of soil nitrogen. The primary productivity of oceans is lower than that of terrestrial ecosystems because the water reflects (or absorbs) much of the light energy before it reaches and is utilized by producers. The table below compares the difference in the net primary productivity of various ecosystems.

Ecosystem Type	Net Primary Productivity	
	$kcal\ m^{-2}\ y^{-1}$	$kJ\ m^{-2}\ y^{-1}$
Tropical rainforest	15 000	63 000
Swamps and marshes	12 000	50 400
Estuaries	9000	37 800
Savanna	3000	12 600
Temperate forest	6000	25 200
Boreal forest	3500	14 700
Temperate grassland	2000	8400
Tundra/cold desert	500	2100
Coastal marine	2500	10 500
Open ocean	800	3360
Desert	< 200	< 840

* Data compiled from a variety of sources.
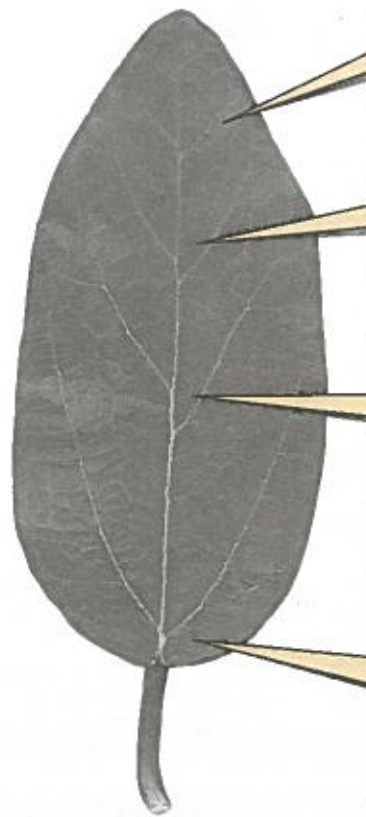
Leaf Area Index (LAI)
Leaf area index is a measure of the total leaf area of a given plant.

Harvestable Dry Biomass
Used for commercial purposes, it is the dry mass of crop available for sale or use.

Relative Growth Rate (R)
Relative growth rate is the gain in mass of plant tissue per unit time.

$$R = \frac{\text{Increase in dry mass in unit time}}{\text{Original dry mass of the plant}}$$

Net Assimilation Rate (NAR)
NAR is the increase in plant weight per unit of leaf area per unit time. Essentially it is the balance between carbon gain from photosynthesis and carbon loss from respiration.

$$NAR = \frac{\text{Increase in dry mass in unit time}}{\text{Leaf area}}$$

Ecosystems

Net Primary Productivity of Selected Ecosystems (figures are in $kJ\ m^{-2}\ y^{-1}$)

< 2500	< 12 500 – 42 000	< 42 000 – 105 000	2500 – 42 000
Arid desert	Temperate forest	Tropical rain forest	Continental shelf waters
Polar tundra and ice desert	Grassland agriculture	Intensive horticulture	Open ocean

1. Briefly describe three factors that may affect the primary productivity of an ecosystem:

   (a) _____

   (b) _____

   (c) _____

2. Explain the difference between **productivity** and **production** in relation to plants: _____

   _____

   _____

3. Suggest how the LAI might influence the rate of primary production: _____

_____

4. Using the data table on the previous page, choose a suitable graph format and plot the differences in the net primary productivity of various ecosystems (use either of the data columns provided, but not both). Use the grid provided, right. Include a title and axes.

5. With reference to the graph:

(a) Suggest why tropical rainforests are among the most productive terrestrial ecosystems, while tundra and desert ecosystems are among the least productive:

_____

_____

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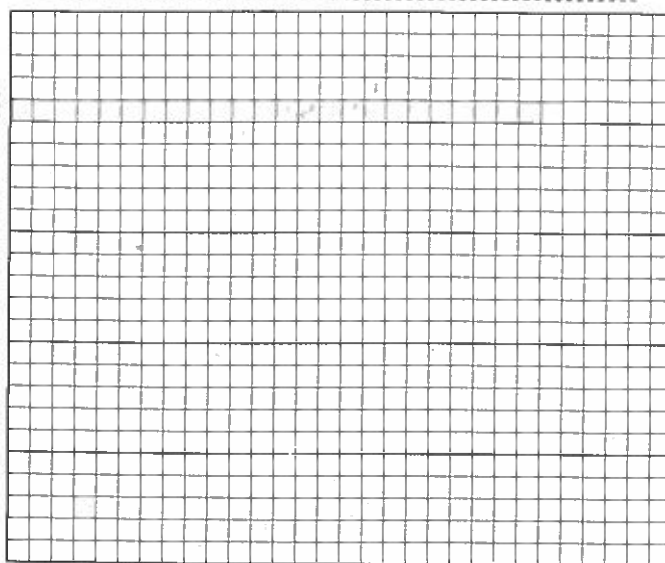
(b) Suggest why, amongst aquatic ecosystems, the NPP of the open ocean is low relative to that of coastal systems:

_____

_____

_____

6. Estimating the NPP is relatively simple: all the plant material (including root material) from a measured area (e.g. 1 m²) is collected and dried (at 105°C) until it reaches a constant mass. This mass, called the **standing crop**, is recorded (in kg m⁻²). The procedure is repeated after some set time period (e.g. 1 month). The difference between the two calculated masses represents the *estimated* NPP:

(a) Explain why the plant material was dried before weighing: _____

_____

(b) Define the term **standing crop**: _____

(c) Suggest why this procedure only provides an estimate of NPP: _____

_____

(d) State what extra information would be required in order to express the standing crop value in kJ m⁻²: _____

_____

(e) Suggest what information would be required in order to calculate the GPP: _____

_____

7. Intensive horticultural systems achieve very high rates of production (about 10X those of subsistence systems).

(a) Outline the means by which these high rates are achieved: _____

_____

(b) Comment on the sustainability of these high rates (summary of a group discussion if you wish): _____

_____

_____

_____