Method Précis: Human Appropriation of Net Primary Production (HANPP)

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The human appropriation of net primary production(HANPP) is an indicator of the intensity of the colonization of ecosystems, namely, the intensity of land use. HANPP is based on the quantification of human interventions in energy flows in ecosystems or, more precisely, in net primary production and the availability of the products of net primary production (primarily biomass) in ecosystems.

Net primary production (NPP) is a measure of the quantity of organic material produced by plants through photosynthesis from inorganic materials. In energetic terms, photosynthesis involves the transformation of radiant energy from the sun into energy stored in chemical compounds. This energy is initially stored in the biomass of plants and then either accumulates in the ecosystem or serves as food energy for humans, animals, fungi and some microorganisms (so-called 'heterotrophic' organisms). During photosynthesis, CO_2 is absorbed from the atmosphere and stored in a variety of chemical compounds in biomass. If this energy is released, for example, through combustion or the metabolism of heterotrophic organisms ('respiration'), then carbon is released into the atmosphere in the form of CO_2. In the short term, ecosystems may represent a 'carbon sink' (that is, absorb more CO_2 through photosynthesis than flows back to the atmosphere due to respiration and combustion) or a 'carbon source' (CO_2 outflows exceed photosynthesis). In the long term and across larger areas, the average absorption and release of CO_2 from ecosystems is largely balanced;[6] that is, CO_2 inflows equal CO_2 outflows (Körner 2009). NPP is an important process in ecosystems; it supplies the entire food energy for humans and all other heterotrophic food webs and provides the basis for the creation of vegetation cover and soils and their associated carbon stocks. NPP is one of the most important indicators of ecosystem capacity and forms the basis for the existence of all biodiversity (Vitousek et al. 1986; Wright 1990).

Insofar as humans use land for their purposes, they intervene in these processes. First, they replace natural ecosystems, such as forests and grasslands, with ecosystems utilized by humans, such as settlement areas, agricultural ecosystems and managed forests (possibly causing soil degradation in the process). The NPP of the ecosystems thus utilized often differs significantly from that of natural ecosystems. The difference between the NPP of potential natural vegetation (NPP_{pot}, NPP of the ecosystem with no human influence) and the vegetation that is predominant due to the land use at a particular point in time (NPP_{act}, *actual* NPP) is defined as $HANPP_{luc}$ (HANPP resulting from land use). Added to this—and this is, in many instances, the actual purpose of land use—is the harvest of biomass for

[6]Exceptions include raised bogs, which are able to create long-term carbon sinks because of the exclusion of oxygen in the soil.

human use ($HANPP_{harv}$, HANPP through harvest). In the current definition, which underpins the research presented in this book (see Haberl et al. 2007, 2014; the notation used here was taken from Krausmann et al. 2013, yet the concept remains the same), $HANPP_{harv}$ is relatively broadly defined and includes those parts of plants that, although they are not themselves economically utilized and actually removed, die off during the harvest. These include, for example, the roots of cereal crops and trees (by contrast, the rootstocks of perennial grasses survive the harvest and are therefore not included in calculations) and the harvest of by-products that remain on the field. In contrast to $HANPP_{harv}$, which is always greater than or equal to zero, $HANPP_{luc}$ can also be less than zero. This is the case when land use increases NPP, which is a common occurrence where artificial irrigation is employed in agriculture. However, land use can also increase NPP in humid regions, for example, in very intensively used agricultural regions. Nonetheless, the NPP_{act} of agricultural ecosystems is often smaller than the NPP_{pot}. The primary purpose of agriculture is to favor the cultivation of plants that produce a greater quantity of plant matter that can be utilized for human food, livestock feed or other economic purposes than natural vegetation would. Examples of usable plant matter are cereal grains and hay rather than unusable leaves or roots. Agriculture is primarily interested in an increase in the economically valuable parts of plants. Whether the NPP of the system rises or falls in the process is not per se important in economic terms but only inasmuch as this produces an increase in the desired harvest. HANPP can therefore be defined as follows (Haberl et al. 2007, 2014):

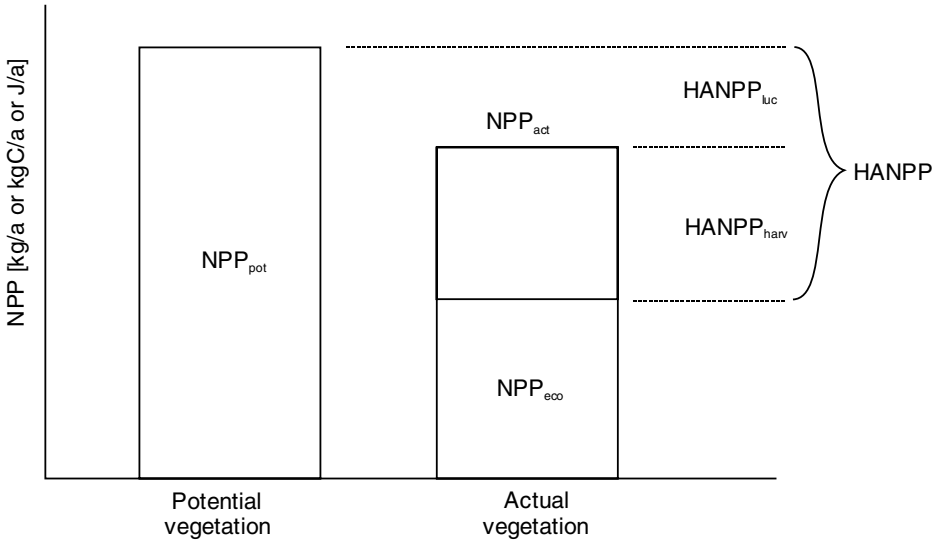

Fig. 14.5 The concept of the human appropriation of net primary production (HANPP)

$$\text{HANPP} := \text{HANPP}_{\text{luc}} + \text{HANPP}_{\text{harv.}} \tag{14.1}$$

If one subtracts the $\text{HANPP}_{\text{harv}}$ from the NPP_{act}, the result is the amount of NPP remaining in the ecosystem after harvest (and thus available to fulfill the ecosystem functions described above, i.e., the food required by heterotrophic organisms or the production/maintenance of carbon stocks). This is defined as NPP_{eco} (NPP remaining in the ecosystem). An equivalent definition of HANPP is, therefore (Fig. 14.5),

$$\text{HANPP} := \text{NPP}_{\text{pot}} - \text{NPP}_{\text{eco.}} \tag{14.2}$$

HANPP can be positive or negative, although a negative HANPP ($\text{NPP}_{\text{eco}} > \text{NPP}_{\text{pot}}$), as a rule, only occurs in arid areas with a low NPP_{pot}, which must be irrigated for agricultural purposes. In other words, HANPP is negative when $\text{HANPP}_{\text{luc}}$ is negative and the absolute value of $\text{HANPP}_{\text{luc}}$ is greater than $\text{HANPP}_{\text{harv}}$. This occurs in arid areas, not in humid regions where intensive agriculture is practiced.

In the literature, other definitions of HANPP are sometimes used, particularly the formulation of Vitousek et al. (1986). The definition used here is a further development of the definition produced by Wright (1990). The influential study by Imhoff et al. (2004) used a consumption-based approach similar to 'embodied HANPP' (Chap. 16). As shown by Haberl et al. (2007), the results of HANPP calculations vary significantly according to the definition used. It is thus of decisive importance that the particular definition used be taken into consideration when interpreting HANPP data.

References

Haberl, H., Erb, K.-H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., et al. (2007). Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. *Proceedings of the National Academy of Sciences, 104*, 12942–12947.

Haberl, H., Erb, K.-H., & Krausmann, F. (2014). Human appropriation of net primary production: Patterns, trends, and planetary boundaries. *Annual Review of Environment and Resources, 39*, 363–391.

Imhoff, M. L., Bounoua, L., Ricketts, T., Loucks, C., Harriss, R., & Lawrence, W. T. (2004). Global patterns in human consumption of net primary production. *Nature, 429*, 870–873.

Körner, C. (2009). Biologische Kohlenstoffsenken: Umsatz und Kapital nicht verwechseln (Biological carbon sinks: Turnover must not be confused with capital). *Gaia—Ecological Perspectives for Science and Society, 18*, 288–293.

Krausmann, F., Erb, K.-H., Gingrich, S., Haberl, H., Bondeau, A., Gaube, V., et al. (2013). Global human appropriation of net primary production doubled in the 20th century. *Proceedings of the National Academy of Sciences, 110*, 10324–10329.

Vitousek, P. M., Ehrlich, P. R., Ehrlich, A. H., & Matson, P. A. (1986). Human appropriation of the products of photosynthesis. *BioScience, 36*, 363–373.

Wright, D. H. (1990). Human impacts on energy flow through natural ecosystems, and implications for species endangerment. *Ambio, 19*, 189–194.