Crucial FEWSION Episode 9
From Pixel to Planet: Earth's Primary Life Support System … And *Why* It's Important To Understand How Humans Are Changing It

[Intro music]

Narrator: When the sun shines on a clear day – every square meter (that's about 3 feet by 3 feet) of the Earth's surface receives on average 1 KWatt of solar energy. This energy powers plants to photosynthesize. And although this process captures just over one thousandth of the torrent of incoming solar energy – it's pretty much the basis of all life on Earth.

Taking in carbon dioxide (or CO_2), and water, plants use that sunshine to make glucose – some of which they use as an internal energy supply. The rest is stored in various carbon compounds in their leaves, stems and roots. This stored plant carbon is called Net Primary Production or NPP for short. And it's the building block for nearly all ecosystems and including everything we eat.

We're going to be hearing about the latest research on how Humans Appropriate that Net Primary Production – which is called H-A-N-P-P or HANPP for short. So, get ready for some *staggering* planetary statistics as we explore HANPP, its history … and what might happen to it in the future. In this episode of *Crucial FEWSION*

[NSF audio logo then music]

Chris Lant: Net Primary Production – I'ts like the GNP of the global ecosystem.. And the extent to which we're using it is a very critical issue. And of all the planetary limits we're hearing about, global NPP is the most essential planetary limit that we MUST live within. I'm Christopher Lant. I'm a professor in the Department of Environment and Society, in the Quiney College of Natural Resources at Utah State University.

Our primary research question is: how does HANPP inform our understanding of environmental sustainability from the scale of a pixel to the planet?

[Music]

My research team includes Suman Paudel, Gustavo Ovando Montejo and Kaeli Mueller.

Suman Paudel: So right now we are working on a project where we calculate Human Appropriation of Net Primary Production at the county level of the US and later downscaling it into 30 meter pixel resolution. My name is Suman Paudel. I'm a PhD student in the Department of Environment and Society, Utah State University. I'm very much excited to downscale the county level HANPP into 30m pixel resolution – its going to be the first HANPP analysis at the 30m scale resolution in the United States.

Gustavo Ovando Montejo: My name is Gustavo Ovando Montejo. I'm an assistant professor in the Department of Environment and Society at Utah State University, Blanding and I'm an expert in Geographic Information Systems or GIS. GIS is essential to study Net Primary

Production because it allows us to map it with a high level of precision in order to understand how NPP varies across the surface of the earth. GIS also allows us to understand the geographic patterns and relationships and how NPP interacts with climate, topography and land use.

Kaeli Mueller: I am studying the relationship between HANPP and biodiversity from 30m pixels and at the scale of entire counties – for every county in the United States. My name is Kaeli Mueller, I'm a Masters student at Utah State University. What I'm really excited to find out about is the relationship between biodiversity and HANPP.

Narrator: Professor Lant – welcome to *Crucial FEWSION.* Many people might not know much about Net Primary Productivity – and even less about how humans appropriate it – you know it sounds bit obscure … is HANPP useful?

CL: HANPP is a *very* useful thing to study, because it tells us what the capacity of the ecosystem is – that would be NPP or Net Primary Productivity, and then how much of that humans are appropriating or using. In a way it's like an ecological footprint. It also has the advantages of having close interactions with other footprints that people might be more familiar with – like carbon footprint and water footprint. I like to call HANPP Ecological Footprint 2.0. HANPP is also spatially specific – and that means, for example that we can analyze it at the scale of a county and then we can downscale it to a pixel and we can also upscale it to states, countries and even the entire planet.

Narrator: When the professor and his team say 'pixel' they doesn't mean something on your laptop screen or smart phone. In *this* research a pixel is 30 meters by 30 meters or 90 feet square … the size of a typical suburban yard or maybe the parking lot outside your apartment. It's the smallest resolution you can get from a satellite image or a land use dataset. At this **pixel scale** researchers can study in detail how Net Primary Production, human appropriation of it, and what remains for the rest of nature, vary from place to place.

At the county scale researchers have used HANPP to measure *how much* ever-growing urban populations rely via trade and transportation, on specialized rural areas for their basic food and other biomass needs. That mainly come from US HANPP-exporting regions such as the Midwest, Central Valley of California and commercial forestry in regions Maine and the Pacific Northwest.

We've talked a lot about these connections in previous episodes of Crucial FEWSION – you might want to check them out. BUT in *this* episode, we're focussing on what HANPP tells us at the scale of nations and the entire planet…

CL: At the scale of entire **countries** HANPP measures the degree to which a country's needs for food, animal feed, biofibre (that would be like wood and cotton) and biofuels are met – or not met, by their natural endowment of net primary production and how much they are leaving for nature to support biodiversity and other kinds of ecosystem services.

There are a couple of different kinds of HANPP. HANPP (land use) and HANPP (harvest). HANPP (land use) is the degree to which human uses of ecosystems actually change and usually decrease the Net Primary Production or the ecological capacity of the land. And then HANPP (harvest) is how much of that we're actually scooping up for our own needs, through crop production, livestock grazing. timber harvesting.

Narrator: Overall this 'actual' figure is typically LOWER than it naturally would be. Why is that?

CL: So, when humans use land, we typically decrease its ecological productivity – and that would be through things like deforestation, desertification, soil erosion, draining wetlands. It's also the case with urban development when we pave over cities or infrastructure.

On the other hand, occasionally human land use actually increases the primary productivity of the land. And that would especially be the case with irrigation and other forms of intensive cultivation, that raise the productivity of the land above what it would be naturally.

THEN there's HANPP (harvest) – when humans actually scoop up biomass and use it economically. That largely occurs through crop production, but also through livestock grazing and harvesting of timber.

[Music]

Narrator: Net Primary Productivity across the globe naturally varies *hugely* … the Western Sahara produces only **10g** of carbon per square meter while in the lush tropics of French Guiana its over **1100g** – **more than 100 times higher than a typical desert**. How much NPP humans appropriate varies even *more*– from a tiny **0.1g** of carbon per square meter in the Western Sahara to **518g** from fertile fields in Bangladesh - **which is a whopping *5000 times more***. In heavily populated and intensively farmed countries a massive amount of NPP is used by humans – **60% in Bangladesh** and **75% in Egypt**, that leaves only 25-40% for nature.

CL: The so-called "New World" continents – Australia, North America, South America – they appropriate more HANPP per capita. But at the same time they appropriate a smaller percentage of the NPP of the land areas of those continents. And this is population relationship – they're less populated. Whereas the Old World continents – Europe, Asia, Africa, appropriate *less* per capita – and that would be an adaptation to ecological scarcity. But in aggregate, because of the higher populations, they appropriate a higher percentage of the land than the New World. For example, India is appropriating at least three quarters of its Net Primary Productivity.

The New World therefore exports HANPP in the form of biomass products – food, timber and so forth, to the Old World, to try and make up the deficiencies in the Old World. HANPP actually varies surprisingly little with income or affluence. And the reason for this is that there's trade-offs. Affluent people consume more biomass through meat, biofuels, wood-based products. BUT developed countries are more agriculturally efficient, so that HANPP (land use) is smaller. For example, in developing countries shifting agriculture would

consume a lot of biomass to produce a small amount of agricultural product. This is why HANPP is a very useful tool to help unpack these relationships with respect to how humans use nature.

Narrator: What happens when you tally up this HANPP data to a *planetary* scale? Well, that's when that the numbers get *truly mind-boggling* …

CL: Global Net Primary Production has been estimated at about 60 **Peta grams of carbon** per year – with HANPP being about a quarter of that – or about 15 Petagrams of carbon a year. A Peta gram is 10^{15} and so when you convert that's billions of tons – so 60 Peta grams of carbon is 60 BILLION TONS.

What's really interesting is the *history* of HANPP. A paper by Krausmann *et al.* at the Institute of Social Ecology in Vienna, estimated that HANPP DOUBLED in the 20th century from about 13% of global Net Primary Productivity up to about 25% of the global total of about 60 Peta grams. So HANPP just about doubled from about 8 to about 15 Peta grams of carbon per year.

Narrator: Another doubling would mean that humans would appropriate **HALF** of all net primary production – which would have **enormous** consequences …

Narrator: What happens if HANPP doubles again globally, Chris?

CL: We might ALL have a situation like India does now - where we're scooping up *almost all the available NPP – but across the entire planet*. That would leave little ecological energy for all other biota on the planet. It would also diminish ecosystem services.

Narrator: What kinds of services?

CL: Pollination, a functioning hydrological cycle, habitat for animals and human cultural activities, climate regulation…

Ecosystem services are worth as much as the whole world economy, according to papers by Costanza et al.

Until now, less densely populated countries and countries with greater ecological resources like the US - have higher levels of HANPP per capita than densely populated countries – like Bangladesh and less fertile countries with low NPP like a lot of countries of North Africa and the Middle East. *Until now* NPP-rich countries have been able to 'overconsume' – for example by eating lots of beef and using biofuels … simply because *the resources are there*. In the U.S. only 15-20% of HANPP harvested is food production; the rest is livestock feed, biofuels and biofiber. But living like this - using up biological resources – has a high opportunity cost; we're foregoing have a landscape richer in biodiversity and ecological services or, alternatively, providing more of the food needs of countries that struggle to be self-sufficient.

Narrator: Until the Industrial Revolution and fossil fuels came along – Net Primary Production was the only source of our energy. Why can't we return to renewable biofuels?

CL: Biofuels won't work *just because they're renewable* – of all solar energy that hits earth **only 0.15%** is captured by plants. Appropriating NPP gives the smallest amount of renewable energy for the biggest trade-off. If we met all our energy needs from biofuels … we'd need to appropriate the *entire growing capacity of the planet!* BUT we're being overwhelmingly bombarded by solar energy – and to a lesser extent by the winds that generates - so, we need to increase our capacity to harness *that* solar and wind power sustainably. I think there's a little bit of a misconception that renewable resources are *always b*etter than non-renewable resources. And that's not necessarily the case when the renewable resources are biological, and we can replace them with other renewable resources – or non-renewable resources.

CL: What we as humans have effectively done **over the last century** is **cut** the carbon content of living biomass in half. At the same time, we've **DOUBLED** the turnover time of that biomass. So that **maintains** the net primary productivity of the planet, **but from a reduced by half carbon stock.**

Narrator: This displaced carbon that was once in our landscapes – where's it all *gone*?

CL: We've pushed it into the atmosphere. Now that carbon *does eventually* cycle out of the atmosphere - but at a much lower rate than we're putting it in.

Over the last 100 years we've effectively moved around 450 Peta grams of carbon – that's 450 billion tons of carbon – that *was* in plants and soils – into our atmosphere. And ***that doesn't even count burning fossil fuels***.

Narrator: It's hard to visualize what that looks like …

CL: Well - **it's half the weight of every living thing currently on the planet**!!!

[Fade up Outro sound design/music]

Outro

KM: If we want to have any chance of conserving significant biodiversity, we have to understand how HANPP affects it – across the *entire* land surface of the earth.

GOM: This research is *so important*, because we need to measure how much humans are taking from the surface to of the earth, *to better understand the limits of our planet*. So we can make the right decisions on how to achieve a sustainable future – and what can be more important than that?

Narrator: You can read the full details of this work in the paper by Paudel *et al.* – check the show notes for more details.

In this episode you heard Suman Paudel, Gustavo Ovando-Montejo, Kaeli Mueller and Professor Christopher Lant.

Crucial FEWSION is produced by me, Diane Hope, for Northern Arizona University's FEWSION project, funded by the National Science Foundation.

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