GLOBAL NUTRIENT LIMITATION IN TERRESTRIAL VEGETATION FROM REMOTE SENSING

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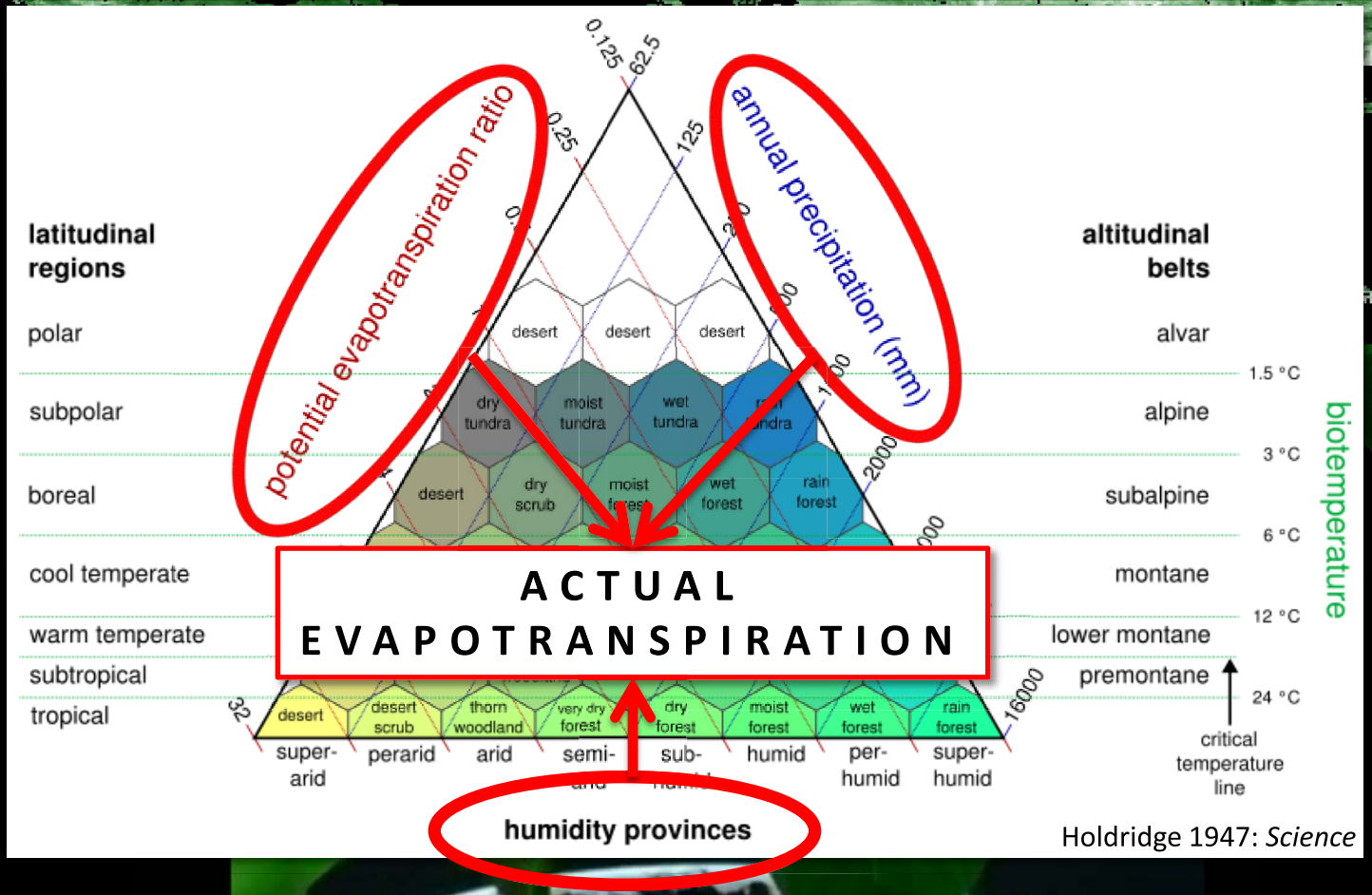

Holdridge 1947: *Science*

$$CO_2 + 2H_2O \xrightarrow{\text{energy (light)}} (CH_2O)_n + H_2O + O_2$$

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THE NATURE OF NUTRIENT LIMITATION IN PLANT COMMUNITIES

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The concept of nutrient limitation was developed in agriculture to refer to the limitation of productivity in an individual plant or monospecific stand because of an inadequate supply of an essential nutrient in the soil (e.g., Ulrich and Hills 1973). If the particular nutrient were available in greater abundance, productivity would increase by definition. We suggest that this concept cannot be extrapolated simply to natural plant communities. For several reasons, plant communities occupying the most infertile sites are not always the most responsive to nutrient addition.

NUTRIENT LIMITATION TO INDIVIDUALS

When a crop plant is grown with a limiting supply of an essential nutrient, it produces less biomass than if the limiting nutrient were more available. The more nutrient-limited an individual is, the more its production increases in response to a large addition of the limiting nutrient (fig. 1). This relationship between nutrient availability and productivity provides an objective criterion for evaluating the extent of nutrient limitation to the growth of individual plants or monospecific stands. Similar growth responses to nutrient addition have been observed in wild plants (Chapin 1980). Wild plants that are restricted to infertile soils, however, generally exhibit lower maximum potential growth rates and respond less to nutrient addition than do related plants from more-fertile soils (fig. 1; see also Mitchell and Chandler 1939; Clarkson 1967; Safford and Filip 1974; Grime 1977; Auchmoody and Smith 1979; Ellis 1979; Chapin 1980; Farmer 1980; Veerkamp et al. 1980; Chapin et al. 1982, 1983).

COMMUNITY NUTRIENT LIMITATION

In individual plants, nutrient limitation is recognized by an increase in growth in response to an addition of the limiting nutrient. The analogous response at the community level is an increase in total community production in response to fertilization. Three major difficulties attend the application of this concept of nutrient limitation to a comparison of communities.

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Nitrogen limitation on land and in the sea: How can it occur?

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Abstract. The widespread occurrence of nitrogen limitation to net primary production in terrestrial and marine ecosystems is something of a puzzle; it would seem that nitrogen fixers should have a substantial competitive advantage wherever nitrogen is limiting, and that their activity in turn should reverse limitation. Nevertheless, there is substantial evidence that nitrogen limits net primary production much of the time in most terrestrial biomes and many marine ecosystems.

We examine both how the biogeochemistry of the nitrogen cycle could cause limitation to develop, and how nitrogen limitation could persist as a consequence of processes that prevent or reduce nitrogen fixation. Biogeochemical mechanisms that favor nitrogen limitation include:

- the substantial mobility of nitrogen across ecosystem boundaries, which favors nitogen limitation in the "source" ecosystem – especially where denitrification is important in sediments and soils, or in terrestrial ecosystems where fire is frequent;
- differences in the biochemistry of nitrogen as opposed to phosphorus (with detrital N mostly carbon-bonded and detrital P mostly ester-bonded), which favor the development of nitrogen limitation where decomposition is slow, and allow the development of a positive feedback from nitrogen limitation to producers, to reduced decomposition of their detritus, and on to reduced nitrogen availability; and
- other more specialized, but perhaps no less important, processes.

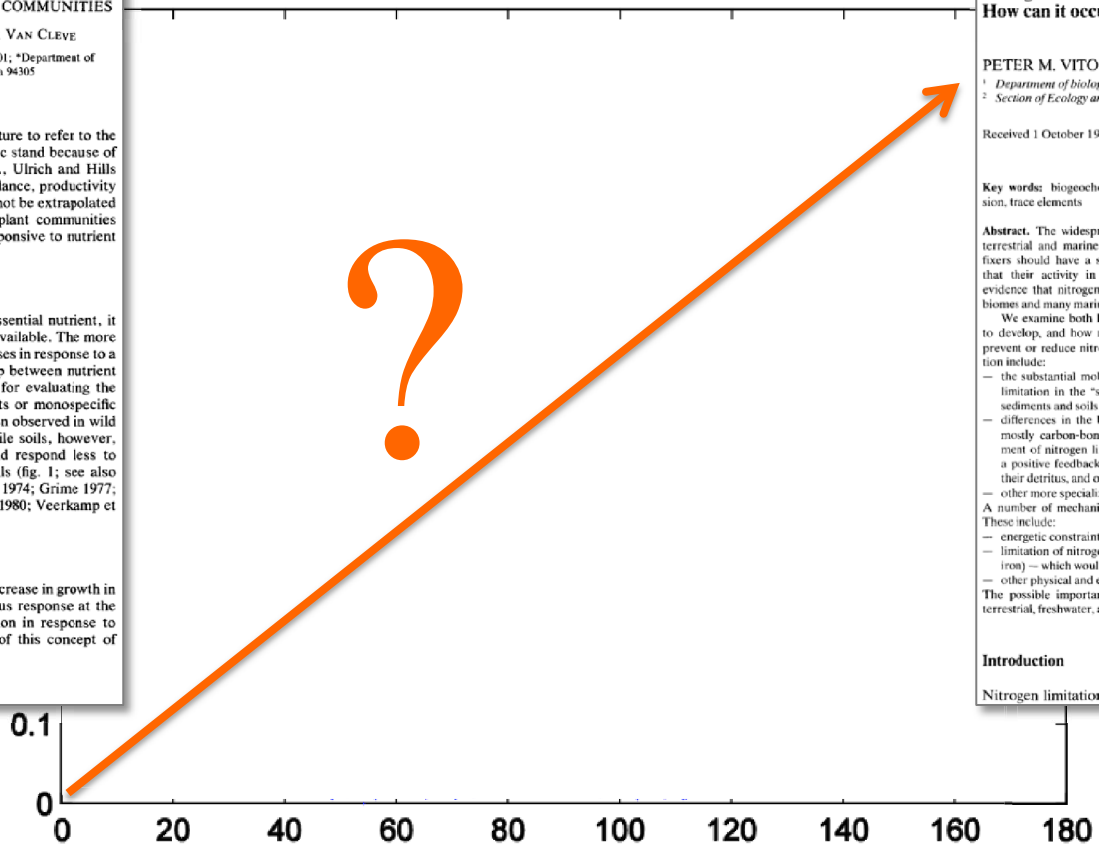
A number of mechanisms could keep nitrogen fixation from reversing nitrogen limitation. These include:

- energetic constraints on the colonization or activity of nitrogen fixers;
- limitation of nitrogen fixers or fixation by another nutrient (phosphorus, molybdenum, or iron) – which would then represent the ultimate factor limiting net primary production;
- other physical and ecological mechanisms.

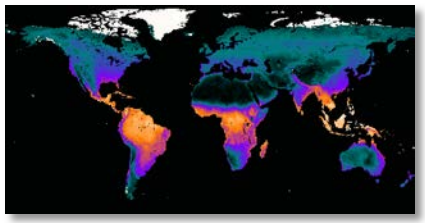
The possible importance of these and other processes is discussed for a wide range of terrestrial, freshwater, and marine ecosystems.

Introduction

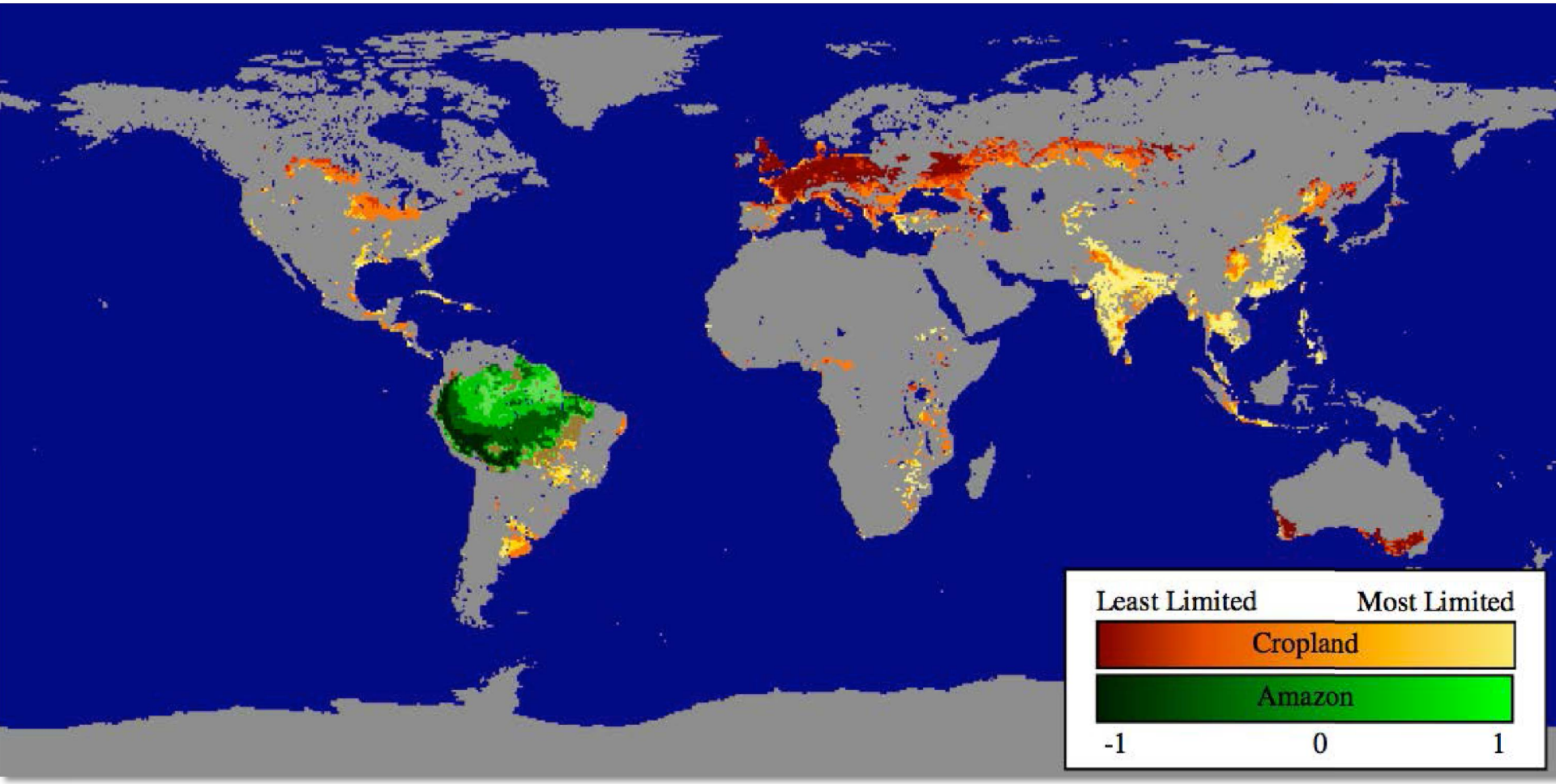
Nitrogen limitation to primary production is believed to be widespread. A



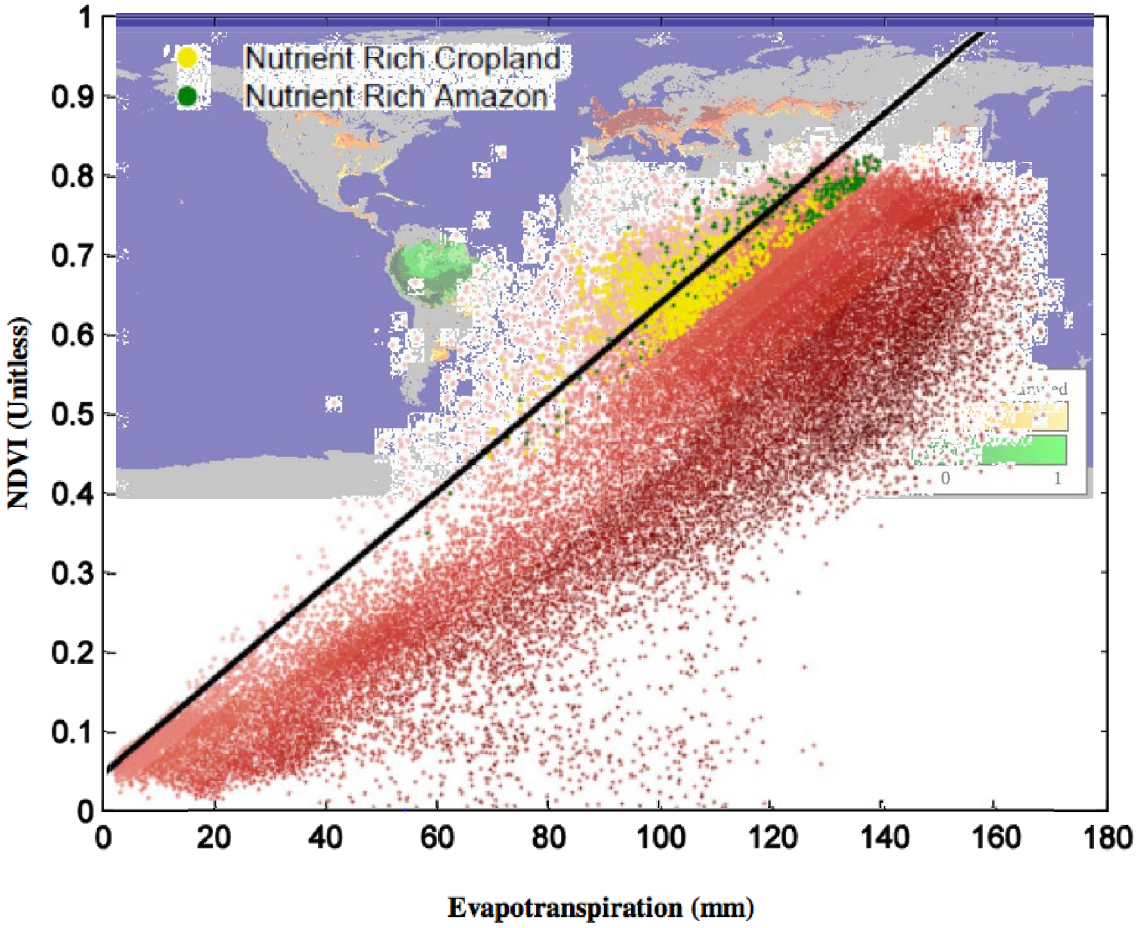
Fisher et al. 2008: *Remote Sensing of Environment*



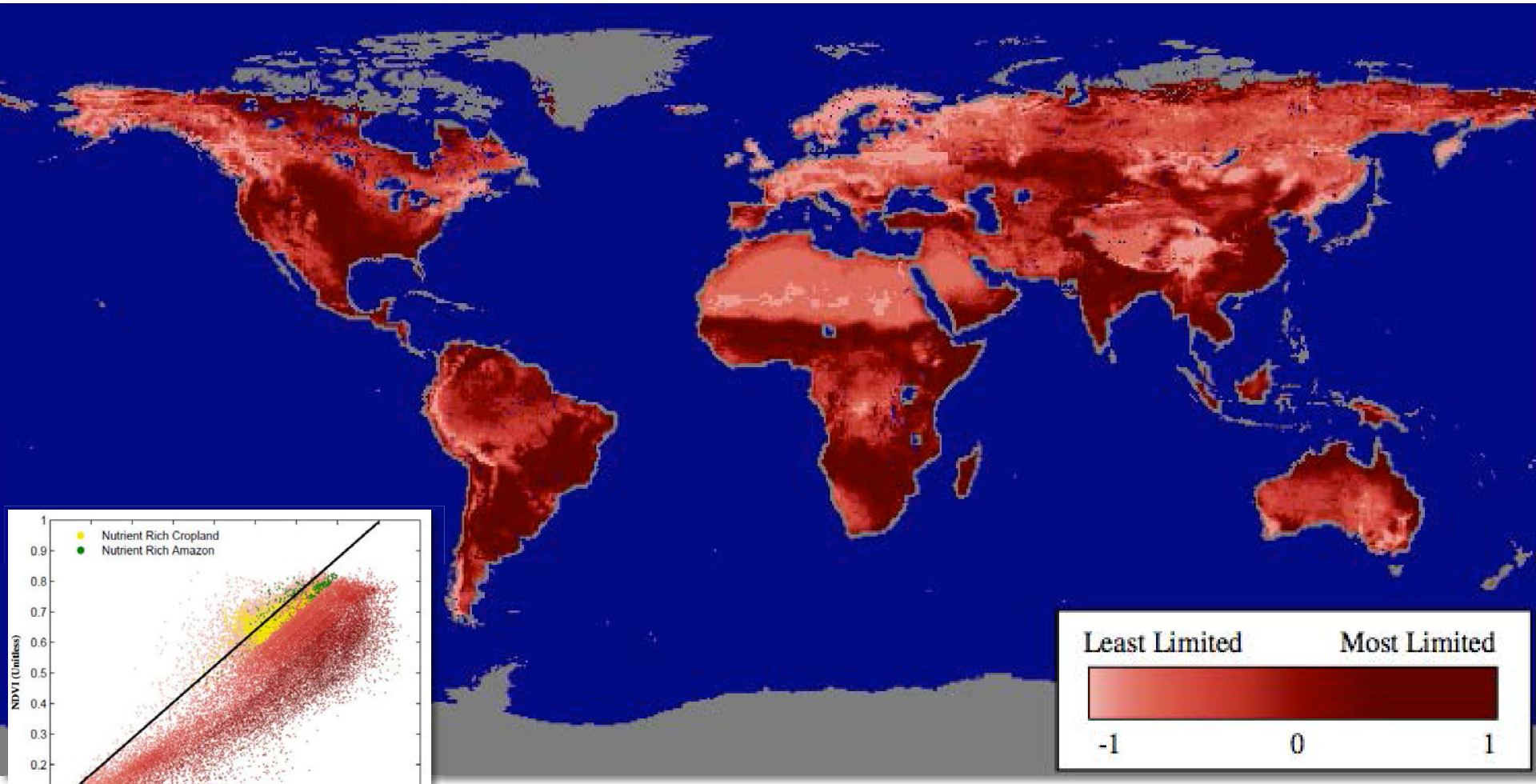
NUTRIENT RICH



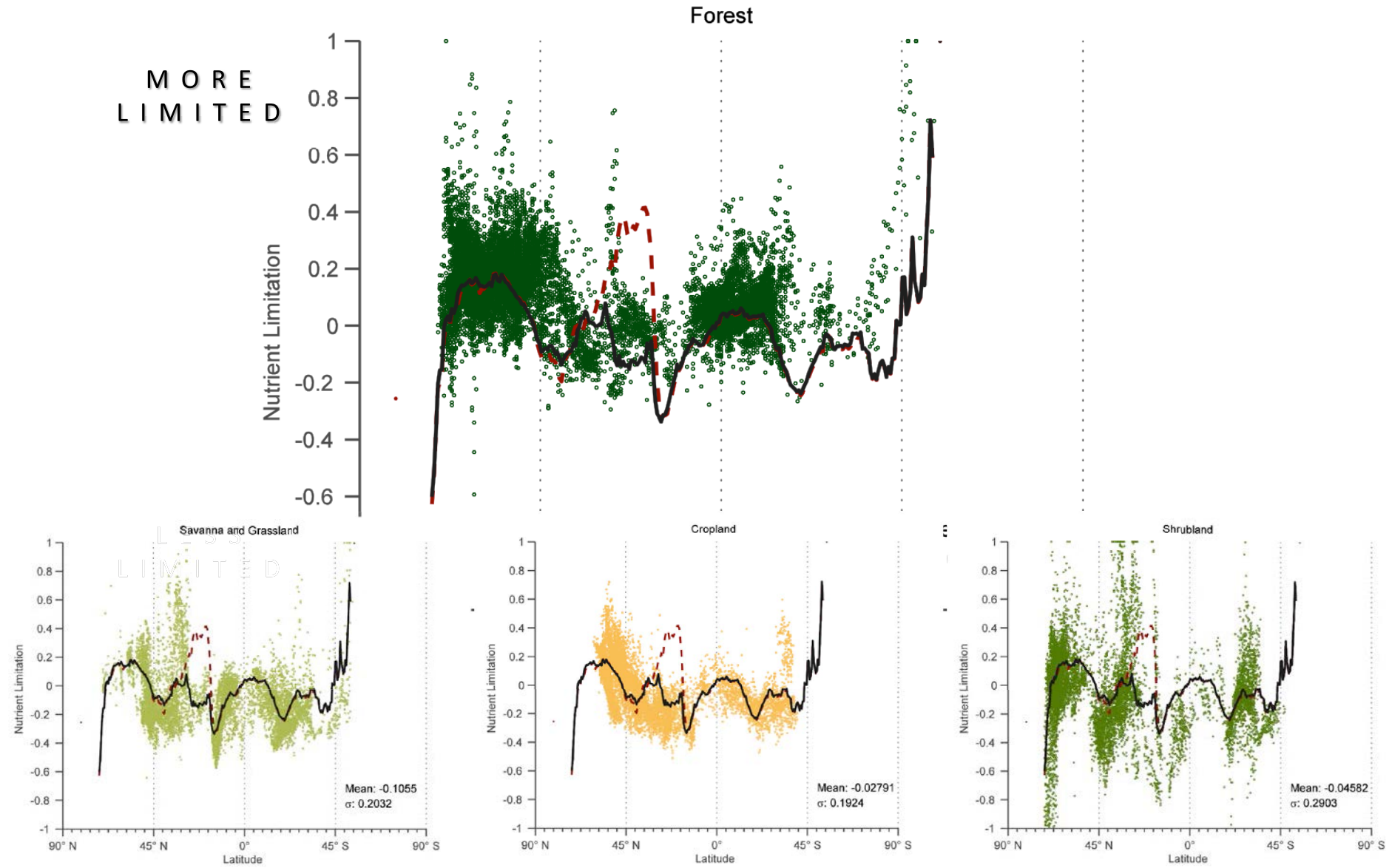
NUTRIENT LIMITATION



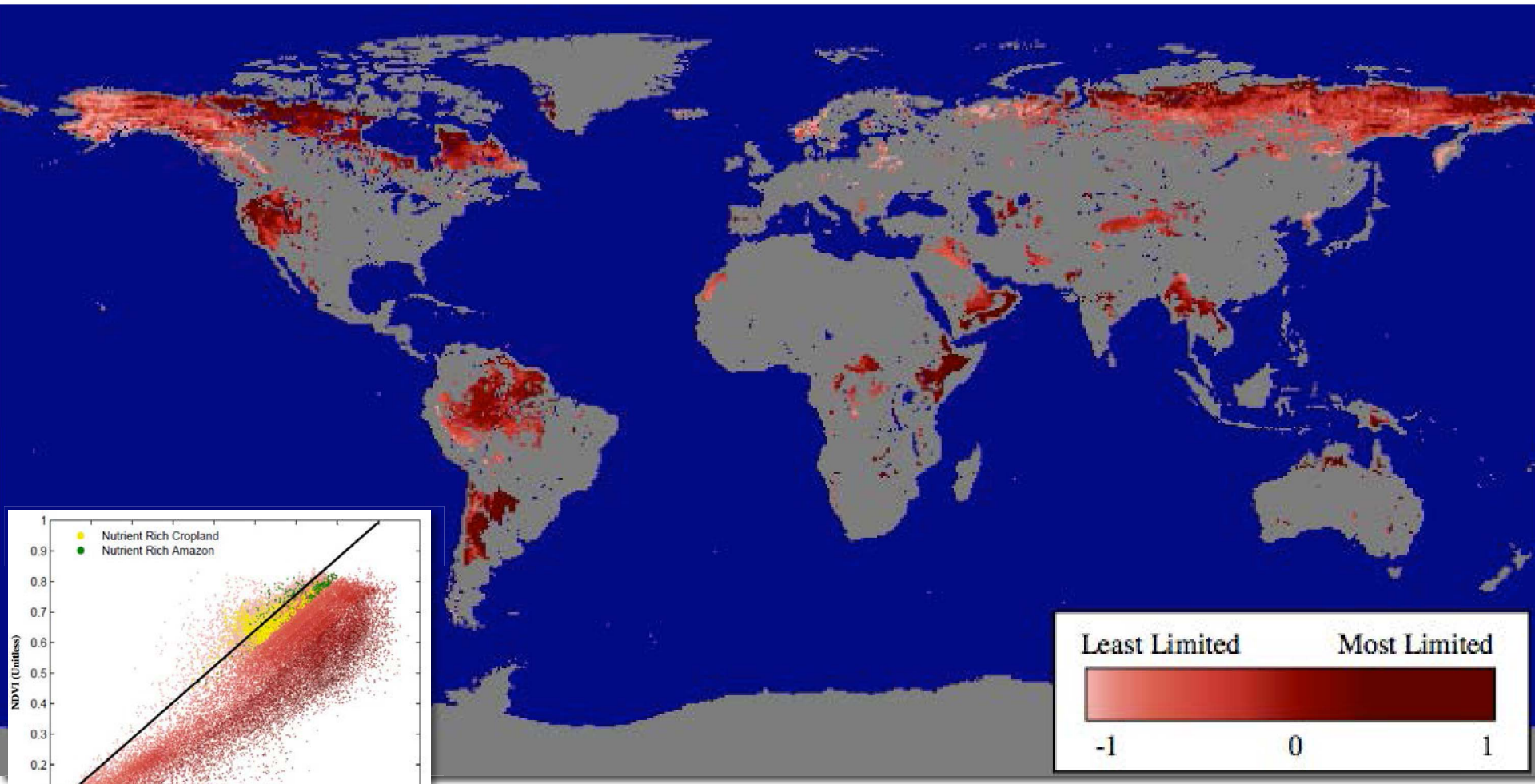
NUTRIENT LIMITATION



NUTRIENTS BY BIOME

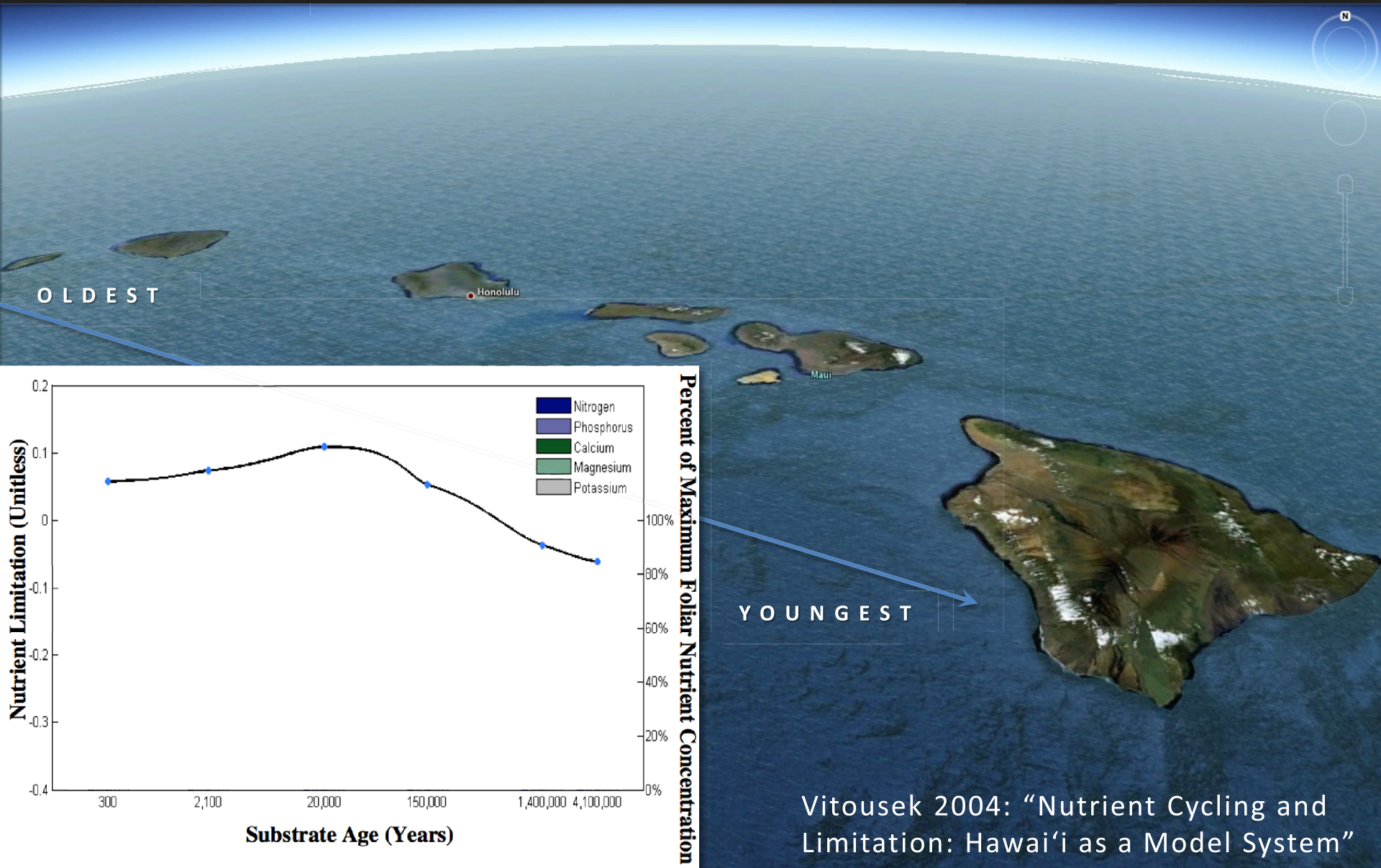


NUTRIENT LIMITATION



Land-use history from Hurtt et al. 2006: *Global Change Biology*

VALIDATION



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