N-dimensional hypervolumes to study stability of complex ecosystems (Barros et al. 2016) - *Read in detail!*

Abstract

Although our knowledge on the stabilising role of biodiversity and on how it is affected by perturbations has greatly improved, we still lack a comprehensive view on ecosystem stability that is transversal to different habitats and perturbations. Hence, we propose a framework that takes advantage of the multiplicity of components of an ecosystem and their contribution to stability. Ecosystem components can range from species or functional groups, to different functional traits, or even the cover of different habitats in a landscape mosaic. We make use of n-dimensional hypervolumes to define ecosystem states and assess how much they shift after environmental changes have occurred. We demonstrate the value of this framework with a study case on the effects of environmental change on Alpine ecosystems. Our results highlight the importance of a multidimensional approach when studying ecosystem stability and show that our framework is flexible enough to be applied to different types of ecosystem components, which can have impor- tant implications for the study of ecosystem stability and transient dynamics.

Introduction

- Ecosystem components range from species/functional groups through to habitat types and structure
- Ecosystems are changing and we need to understand there responses
- Stability is multifaceted...
- Biodiversity-Ecosystem Functioning (BEF)
  - Understanding how biodiversity maintains and promotes productivity
- Fewer studies have looked at perturbation-biodiversity
  - Functional diversity can change across environment /disturbance gradients
  - Relationship of ecosystem function and biodiversity
- **Ecosystem stability is no easily summarised by a single metric**
  - Using multiple components should provide better results...
  - Components often have temporal oscillations..
    - In 2D these converge on a point...
    - in 3D (and n-dimensions) it becomes more complex ⇒ N-Dimensional Hypervolumes!
- N-Dimensional Hypervolumes
  - These oscillations become a trajectory in n-dimensional space
  - A cloud of points...
  - If conditions are disturbed than the trajectory will change ⇒ new hypervolume
  - They can be used to test departure from a stable state
  - Also convergence on new stable state or return to old (i.e. different measure of stability can be tested)
- Choosing components (Choice of components depends on the kind of study)
  - Stability of biodiversity at community scale
    - Time series of species abundances
    - Community weighted means (CWMs) and varience (CWVs) of functional traits
  - Larger Scale

    * Taxonomic functional traits
    * Phylogenetic diversity metrics
  - Ecosystem Mosaics
    * Proportions of habitat patches

The Framework!

- Step 1 - Choice of Components
  - Their example contructs n-dimensional hypervolumes in time-series of n-ecosystem traits at equilibrium.
  - My study will also look at space
- Step 2 - Data Treatment and Hypervolume calculation
  - Number of dimensions must be fixed to maintain comparability
  - Need comparable units (centred and scaled)
  - Not correlated!! (Look at PCAs, PCoAs etc to get around this?)
  - Try not to exceed 5-8 variables to avoid disjointed and holey hypervolumes
  - Hypervolume calculations follow a multi-dimensional kernal density estimator procedure. See Blonder et al. (2014)
- Step 3 - Comparing hypervolumes and analysis of community changes
  - Sufficiently large changes in environmental conditions should produce shifts in community structure. $\Rightarrow$ These should be seen in the constructed hypervolumes...
  - Three possible measures
    * Overall similarity $\Rightarrow$ Overlap
    * Changes in mean values of components $\Rightarrow$ Distance between centeroids
    * Changes in Variance $\Rightarrow$ Changes in hypervolume size
- Step 4 - Complementary metrics for more detailed analysis
  - Hypervolume comparisons don't really tell you what changed so there is need for further analysis looking at the specific components used...

Working Example

- Based on simulated data (Don't really understand this!)
- Habitats under climate change (CC) and land use change (LUC)
- calculated hypervolume every 15 years of simulation
- used actual abundances instead of relative - not interested in dominance/structural changes.
  - This also meant the differences between hypervolumes were bigger (easier to see)
- hypervolume overlap was significantly affected by CC & LUC
- hypervolumes on traits and on Plant Functional Diversity (PFDs)
- Trait hypervolumes tended to be smaller

Discussion

- Environmental changes impact biodiversity at many levels
- Need to measure contribution of different taxanomic, functional or landscape entities
- Analysing Magnitude of Change
  - Size ⇒ Variance
  - Mean ⇒ Position of centeroid
  - Similarity ⇒ Overlap
- **N-dimensional hypervolumes do not summarise components as one metric but describe them as an n-dimensional cloud!**
- Assessing type of change
  - can be informative about what facets of an ecosystem were most affected by ecosystem perturbation
  - complimentary measures are important though!
- Following changes in time
  - Since hypervolumes define different ecosystem structures they can be used to test all types of ecosystem stability
    - Persistence ⇒ Time before change once perturbation starts
    - Resilience ⇒ Return to state after perturbation
    - Resistance R ⇒ Amount of change after perturbation
    - Variabiltiy ⇒ Variation before vs after perturbation
  - Implications for ecosystem services
  - Small overlaps may still indicate changes in ecosystem state. I think this study saw overlaps = 0 this is not as likely on real data!.
- Advantages of hypervolumes
  - Ecosystems are made up of a multiplicity of components
  - Allows for detec tion of finer changes
  - negates problems with habitat mosaics and ecotone interactions
  - Can be used to predict future responses and resilience to extreme events/perturbations

Predicting ecosystem stability from community composition and biodiversity (de Mazancourt et al. 2013) - *Intro and Discussion*

Abstract

As biodiversity is declining at an unprecedented rate, an important current scientific challenge is to understand and predict the consequences of biodiversity loss. Here, we develop a theory that predicts the temporal variability of community biomass from the properties of individual component species in monoculture. Our theory shows that biodiversity stabilises ecosystems through three main mechanisms: (1) asynchrony in species' responses to environmental fluctuations, (2) reduced demographic stochasticity due to overyielding in species mixtures and (3) reduced observation error (including spatial and sampling variability). Parameterised with empirical data from four long-term grassland biodiversity experiments, our prediction explained 22–75% of the observed variability, and captured much

of the effect of species richness. Richness stabilised communities mainly by increasing community biomass and reducing the strength of demographic stochasticity. Our approach calls for a re-evaluation of the mechanisms explaining the effects of biodiversity on ecosystem stability.

Introduction

- Ecosystems undergo temporal stressors which impact their stability
- It seems intuitive that biodiversity increases stability with different species compensating for each other when lost. But there has been lots of debate about the relationship of diversity and stability since the 1970's
  - This is mainly because while diversity increases stability of overall biomass it decreases stability of individual species abundances
- A number of theories have been developed to explain diversities stabilising effect on aggregate ecosystem properties.
  1. Statistical approach based on phenomenological relationships
  2. A stochastic approach describing population dynamics but not specifically species interactions
  3. A general population dynamical approach
  4. Specific models of interspecific competition
- these all kinda describe whats going on but not a mechanism! ⇒ This is still contentious
- These are not able to predict ecosystem stability from the properties of component species
- This study comes up with a new theory to do just that...

Theoretical Model

- Discrete-time version of Lotka-Volterra model incorporating environmental and demographic stochasticity
- Description of model (not really important for me)
- Lots of maths and results...

Discussion

- Their model explained 22-75% variance in the aboveground community biomass in 4 long-term experiments
- Summed species covariances are unlikely to provide a mechanistic explanation for community stability
- Asynchrony of species environmental responses is the basic mechanism of the 'insurance hypothesis'
- Their model also shows these. Asynchronous species responses ⇒ Greater community stability
- Reduced demographic stochasticity ⇒ increased community biomass
  - Species richness increases community biomass, though complimentary species or selection of more productive species ⇒ known as overyielding
  - Their study when tested on empirical data showed this was happening...
- Effect of diversity on ecosystem stability through reduced observation errors
  - If species biomasses are measured individually, the higher the diversity the more the error will even out across the whole community biomass...
  - Common species weigh more on the variability than rare species.
  - Maybe this is just a methodological problem?

- all this stuff is based on experiments in monocultures...

Network spandrels reflect ecological assembly (Maynard et al. 2018) - *Intro and Discussion*

Abstract

Ecological networks that exhibit stable dynamics should theoretically persist longer than those that fluctuate wildly. Thus, network structures which are over-represented in natural systems are often hypothesised to be either a cause or consequence of ecological stability. Rarely considered, however, is that these network structures can also be by-products of the processes that determine how new species attempt to join the community. Using a simulation approach in tandem with key results from random matrix theory, we illustrate how historical assembly mechanisms alter the structure of ecological networks. We demonstrate that different community assembly scenarios can lead to the emergence of structures that are often interpreted as evidence of 'selection for stability'. However, by controlling for the underlying selection pressures, we show that these assembly artefacts or spandrels are completely unrelated to stability or selection, and are instead by-products of how new species are introduced into the system. We propose that these network-assembly spandrels are critically overlooked aspects of network theory and stability analysis, and we illustrate how a failure to adequately account for historical assembly can lead to incorrect inference about the causes and consequences of ecological stability.

Introduction

- Ecological networks tend to be strikingly non-random
  - It is hypothesised that this occurs because selection 'prunes' unstable configurations, resulting in stable patterns
  - for example wildly fluctuating networks would not be expected to persist through time die to stochastic extinctions
- but it could be that these structures are just 'artefacts of assembly' with no inherent connection to stability
- Assembly of biological systems is dictated by two forces
  1. How, when and why variation is introduced into a system.
  2. Selective mechanisms which determine what features persist at what frequencies.
- While selection is a dominant force we must not forget assembly constraints!
  - It is possible for features which appear to have current utility to have been occurred as a by-product of the way the system was formed and have no adaptive origin.
  - dubbed the 'network spandrel' - a nod to cathedral archways which appear to have been selected but are in fact a by-product of construction.
- A 'network spandrel' refers to any network property which emerges as a by-product of how the species joins the community.
- Disentangling whether an empirical pattern has emerged due to assembly constraints or selection is very difficult. Requires experimental, observational and theoretical evidence.

Assembling Ecological Communities

- Again they use the Lokta-Volterra model.
- They set the parameters to reach a steady state

- After each equilibrium is reached they add a new species to the simulated community, then run to equilibrium again. This new species may or may not establish, and may or may not lead to one or more extinctions of other species.
- some stuff about methods, summarised well in fig1.
- lots of results which are interesting but difficult to summarise

Discussion

- Biological systems are not only the result of selection! But also how variation is introduced into systems!
- This study shows that different assembly processes leave different fingerprints on the resulting network giving the appearance of different selective pressures.
- Spandrels reflect the historic processes which shap ed a system (while not specifically saying anything about selection)
- not accounting for spandrels leads to incorrect inferences about selection and stability.

New Approaches for delineating n-dimensional hypervolumes (Blonder et al. 2018)

Abstract

1. Hutchinson's n-dimensional hypervolume concept underlies many applications in contemporary ecology and evolutionary biology. Estimating hypervolumes from sampled data has been an ongoing challenge due to conceptual and computational issues.
2. We present new algorithms for delineating the boundaries and probability density within n-dimensional hypervolumes. The methods produce smooth boundaries that can fit data either more loosely (Gaussian kernel density estimation) or more tightly (one-classification via support vector machine). Further, the algorithms can accept abundance-weighted data, and the resulting hypervolumes can be given a probabilistic interpretation and projected into geographic space.
3. We demonstrate the properties of these methods on a large dataset that character- ises the functional traits and geographic distribution of thousands of plants. The methods are available in version $\geq$2.0.7 of the HYPERVOLUME R package.
4. These new algorithms provide: (i) a more robust approach for delineating the shape and density of n-dimensional hypervolumes; (ii) more efficient performance on large and high-dimensional datasets; and (iii) improved measures of functional diversity and environmental niche breadth.

Introduction

- Over the last decade there has been a number of studies using n-dimensional hypervolumes as a central concept
- Assuming a system can be characterised by a set of independent axes, these axes would constitute a n-dimensional euclidean space.
- Choosing how to delineate this n-dimensional space is a bit controversial. There has historically been differences when niche-data is used vs trait-data
- All depends on the goals of the analysis
- Hypervolume R package uses a Monte Carlo approach. It can describe complex shapes, measure their volume and perform set operations (to find distance, intersections etc).
- This paper develops the hypervolume concept and better algorithms to delineate them.

New Hypervolume construction methods

- Two methods
  - Gaussian: this kernal decays towards zero in all directions, if you believe the data is an unbiased sample from a probability distribution then use this.
  - Support-vector-machine: provides a smooth fit around the data. Use this if you think the extremes of the data represent the true bounds.
- When calculating hypervolumes the max number of dimensions n should be no more than $\log m$ where m is the number of data points.
- They use a hyperelliptical uniform sampling algorithm

Other New Functionality

- hypervolume_general_model, this effectively maps an n-dimensional hypervolume to on-dimensional Euclidean space.
- Ability to weight data
- Ability to create geographic maps for species distribution modelling

Demonstration Analysis

- Functional trait analysis: Three trait values
- Niche Analysis: Three climatic variables

Logging disturbance shifts net primary productivity and its allocation in Bornean tropical forests (Riutta et al. 2018)

Abstract

Tropical forests play a major role in the carbon cycle of the terrestrial biosphere. Recent field studies have provided detailed descriptions of the carbon cycle of mature tropical forests, but logged or secondary forests have received much less attention. Here, we report the first measures of total net primary productivity (NPP) and its allocation along a disturbance gradient from old-growth forests to moderately and heavily logged forests in Malaysian Borneo. We measured the main NPP components (woody, fine root and canopy NPP) in old-growth (n = 6) and logged (n = 5) 1 ha forest plots. Overall, the total NPP did not differ between old-growth and logged forest (13.5 ± 0.5 and 15.7 ± 1.5 Mg C $ha^{-1}year^{-1}$ respectively). However, logged forests allocated significantly higher fraction into woody NPP at the expense of the canopy NPP (42% and 48% into woody and canopy NPP, respectively, in old-growth forest vs 66% and 23% in logged forest). When controlling for local stand structure, NPP in logged forest stands was 41% higher, and woody NPP was 150% higher than in old-growth stands with similar basal area, but this was offset by structure effects (higher gap frequency and absence of large trees in logged forest). This pattern was not driven by species turnover: the average woody NPP of all species groups within logged forest (pioneers, nonpioneers, species unique to logged plots and species shared with old-growth plots) was similar. Hence, below a threshold of very heavy disturbance, logged forests can exhibit higher NPP and higher allocation to wood; such shifts in carbon cycling persist for decades after the logging event. Given that the majority of tropical forest biome has experienced some degree of logging, our results demonstrate that logging can cause substantial shifts in carbon production and allocation in tropical forests.

Introduction

- The tropical forest biome plays a dual role in the global carbon cycle
  - Carbon sink for approx 40% of global land C
  - Approx 90% of C emissions from land use change
- Selective logging is changing the nature of tropical forest
  - Moves from slow-growing, conservative, shade tolerant species to fast-growing, light demanding species
  - In short term it decreases NPP but long term woody biomass accumulation is higher in logged forest as they devote more metabolism to rapid-growth and resource acquisition over maintenance and defence (as old growth does)
- Questions of the study:
  - How does allocation of NPP vary along disturbance gradient
  - Are the high woody growth rates in logged forest a result of increased NPP, shift in allocation to favour woody production or a bit of both.
  - How much does species turnover (presence of pioneer species) impact change in NPP across disturbance gradient
  - Contribution of shifts in tree carbon budgets vs changes in density and structure in determining net change of NPP

Materials and Methods

- Study Sites:
  - Table 1. has a really good summary...
  - no clear differences in soil-nutrition and physical properties between sites
- NPP estimates
  - woody NPP (stems, coarse roots and branches)
  - canopy NPP (leaves, twigs and reproductive parts)
  - fine root NPP
  - Woody NPP
    * sum of stem, coarse root and branch turnover NPP
    * measured all tress >10cm diameter at 1.3m.
    * all plots recensused at least once
    * height estimated visually on first census and then calculated based on diameter-height relationship on subsequent censuses
    * aboveground woody biomass estimated with allometric equations with diameter, height and wood density (from global wood density database)
  - Canopy NPP
    * litter fall was used as proxy
  - Fine root NPP
    * measured with root in growth cores - at installation all roots were removed and replaced with root free soil...

        * harvested every 3 months
    - Missing components of NPP
        * things like allocation to mycorrhizae, volatile organic emissions and loss to herbivory are not included and would likely contribute 13% of NPP
- Data Analysis
    - the aim is to quantify the spatial variation in NPP (within and among plots, between old and new-growth forest). So they pooled all temporal replicates...

Forest quality, forest area and the importance of beta-diversity for protecting Borneo's beetle biodiversity (Sharp et al. n.d.)

Abstract

1. The lowland forest of Borneo is threatened by rapid logging for timber export and clearing for the expansion of timber and oil palm plantations. The combination of these two processes leaves behind landscapes dotted with small, often heavily degraded forest fragments. The biodiversity value of such fragments, which are easily dismissed as worthless, is uncertain.
2. We collected 187 taxa of staphylinid beetles across a land-use gradient in Sabah, Malaysia, spanning pristine tropical lowland forest to heavily-degraded forest. Using these data, we identified shifts in alpha-, beta-, and gamma-diversity in response to forest quality and forest area, and applied our findings from continuous expanses of forest to make predictions on hypothetical forest fragments.
3. We found that maintaining high forest quality is important for conserving rare taxa (those important for conserving biodiversity per se), and that very small fragments (10 ha) are likely to harbour the same richness of staphylinids as larger fragments (100 ha) of the same forest quality. We estimate a decline in staphylinid richness of just 16% following the removal of 90% of the vegetation biomass from a fragment within this area range.
4. Maintaining large forest areas is important for conserving common taxa, likely to be more important for conserving ecosystem functioning. Our analyses suggest that 100 ha fragments of heavily-degraded forest can support the same or greater diversity of common taxa as 100 ha fragments of pristine forest. We find that reducing 100 ha fragments to 10 ha fragments will likely result in the loss of just 11% of common taxa diversity.
5. Despite significant declines in alpha-diversity, beta-diversity within small rainforest fragments will likely partially mitigate the loss of gamma-diversity, reinforcing the concept that beta-diversity is a dominant force determining the conservation of species in fragmented landscapes.
6. Synthesis and applications. In contrast to previous findings on larger animals, our results suggest that even small fragments of degraded forest might be important reservoirs of invertebrate biodiversity in tropical agriculture landscapes. These fragments should be conserved where they occur and form an integral part of management for more sustainable agriculture in tropical landscapes.

Introduction

- Borneo is super diverse, but this diversity is under threat.
- Need to understand the consequences of land use change to make 'informed management recommendations'
- Previous studies show that remaining fragments of forest support a greater diversity than palm plantation (though far less than pristine continuous forest)
- Important that at least fragments are spared.
- Logged forest is also important! Now treated as a discrete habitat type (Old Growth, Logged, Palm Plantation)

- But! logged forest is very variable in disturbance type/amount. It is better to put habitat quality on a continuous scale to better understand response to disturbance.

- measuring impact of habitat change is difficult cause it changes between different measures of diversity.
- Diversity:
  - at one point = Alpha
  - between points = Beta
  - Total = Gamma
- studies usually look at species richness but this disregards the numbers of the different species...
- You want to protect rare species but also common species which are probably more important for ecosystem functioning.
- beta diversity is often neglected (and has issues) given this we remain pretty uninformed on the response of beta-diversity to land use change in Borneo but is really important especially when looking at spatial differences in diversity
- there are equations which allow the comparison of different measures of diversity
- its good to study a taxon which is abundance and ecologically important (enter beetles)
  - very specious abd functionally diverse
- uses Jost's diversity index to quantify impacts of forest quality and forest area on the richness and community composition.

Material & Methods

- Study Site
  - SAFE in Sabah Malaysia
  - fractal sampling pattern specifically designed to study diversity at multiple spatial scales
  - logged forest with widely varying quality
- Insect Sampling
  - traps were combo (pitfall, flight-interception and malaise)
  - sampled twice
  - Staphylinid beetles identified to lowest taxonomic level. Aleocharinae removed from analysis as too difficult to identify
- Calculating Diversity metrics
  - used josts equations
  - removed traps combinations with no staphylinid beetles
  - combinations of three traps were used as the simplest method of generating 2D shapes
  - three weightings (equal, favour rare, favour common)
  - these three weightings encompass arguments around species richness/diversity stuff...
- Defining forest area and forest quality variables
  - used AGB - depending on where the three points fell in the fractal design depended on how AGB was calculated (mean of different sites)
  - each three-trap combination was assigned a continuous forest quality value.

- did some trickery to make sure forest area and AGB were nor correlated.
- selecting models of forest area and forest quality
  - Generalised linear mixed models were fitted to predict abundance from forest quality.
  - model selection using BIC
- creating nominal forest fragments
  - ...

Results

- ...

Discussion

- protecting primary forest is best for conserving species abundance and richness
- preserving forest area is better to maximise the diversity of common species which are likely to contribute more to ecosystem functioning
- habitat quality had a greater impact than area on invertebrate taxa richness.
- more area = more specialist species!
- forest areas < 116ha, habitat quality is more important than size
- beta diversity has increased in some poor forest quality plots not because its more spatially heterogeneous but cause common species are less abundant.
- beta diversity is important for overall species richness and gamma diversity
- in highly disturbed forest alpha diversity is lower suggesting that the community is dominated by a small number of taxa
- evidence that logging has changed the makeup of the community but no overall reduction in diversity.
- no effect of habitat shape found

Vertical stratification of adult mosquitoes (Diptera: Culicidae) within a tropical rainforest in Sabah, Malaysia (Brant et al. 2016) -

Abstract

Background: Malaria cases caused by *Plasmodium knowlesi*, a simian parasite naturally found in long-tailed and pig-tailed macaques, are increasing rapidly in Sabah, Malaysia. One hypothesis is that this increase is associated with changes in land use. A study was carried out to identify the anopheline vectors present in different forest types and to observe the human landing behaviour of mosquitoes.

Methods: Mosquito collections were carried out using human landing catches at ground and canopy levels in the Tawau Division of Sabah. Collections were conducted along an anthropogenic disturbance gradient (primary forest, lightly logged virgin jungle reserve and salvage logged forest) between 18:00 and 22:00h.

Results: *Anopheles balabacensis*, a vector of *P. knowlesi*, was the predominant species in all collection areas, accounting for 70% of the total catch, with a peak landing time of 18:30–20:00h. *Anopheles balabacensis* had a preference for landing on humans at ground level compared to the canopy ($p < 0.0001$). A greater abundance of mosquitoes were landing in the logged forest compared to the primary forest ($p < 0.0001$). There was no difference between mosquito

abundance in the logged forest and lightly logged forest ($p = 0.554$). A higher evening temperature ($p < 0.0001$) and rainfall ($p < 0.0001$) significantly decreased mosquito abundance during collection nights.

Conclusions: This study demonstrates the potential ability of *An. balabacensis* to transmit *P. knowlesi* between canopy-dwelling simian hosts and ground-dwelling humans, and that forest disturbance increases the abundance of this disease vector. These results, in combination with regional patterns of land use change, may partly explain the rapid rise in *P. knowlesi* cases in Sabah. This study provides essential data on anthropophily for the principal vector of *P. knowlesi* which is important for the planning of vector control strategies.

Introduction

- It has been proposed that land-use change has increased the interaction of humans with malaria vectors due to the encroachment of humans into previously forested areas.
- As the transmission of malaria is increasing its important to identify the vectors and their biting preference.

Methods

- Study Site
  - Tawau division of Sabah, Malaysia
  - Three areas along forest disturbance gradient; primary lowland, virgin jungle reserve, twice logged disturbed
  - Three survey points with a minimum of 500m separation were used at each site.
  - Survey points are a subset of SAFE
- Data Collection
  - April to July 2014
  - Human landing catches between 18:00 and 22:00
  - At ground and (2/3) canopy height
  - All mosquitoes which landed on the surveyor were collected and identified
- Meteorological data
  - Air temp and relative humidity measured at each site
  - nightly rainfall from nearest rain gauges
  - lunar illumination, cloud cover, 'unusual climatic events' also recorded
- Data Analysis
  - Calculated measures of diversity (simpsons and shannons)
  - And species accumulation curves
  - measures of 'true richness' were also predicted
  - Generalised Linear Mixed Effects model to analyse the impact of canopy heigh and forest quality on mosquito abundance.
  - Compared abundance of vector and non-vector species
  -

Results

- Mosquito Abundance
  - 807 mosquitoes collected
  - 39 nights
  - measures of diversity differed between forest types - more species in logged forest and at ground level

Stopped being relevant

The Stability of Altered Forest Ecosystems Project: Investigating the design of Human-Modified Landscapes for Productivity and Conservation (Turner et al. 2012)

Abstract

With growing global demands for palm oil, there is mounting pressure on limited natural resources to support the dual services of agricultural productivity and maintenance of biodiversity. Balancing these two services requires detailed research on four themes: i) the impacts on biodiversity of forest conversion and fragmentation, ii) which factors drive these changes in biological communities, iii) what impacts changes have on ecosystem functioning and, iv) the management and design of multifunctional landscapes. Such questions are often difficult to answer as data must be collected at the landscape scale and over long time periods. The Stability of Altered Forest Ecosystems (SAFE) Project (see www.safeproject.net for more details) is a ground-breaking scientific study based in Sabah, Malaysia which investigates the impacts of forest conversion to oil palm on biodiversity, ecosystem functioning and productivity. Funded by the Sime Darby Foundation with support from Benta Wawasan and the Sabah Forestry Department, the project is a collaboration between research institutions and the oil palm industry. The project takes advantage of a 7 900 ha area of forest which was scheduled for conversion to oil palm in 2012, allowing the consequences of habitat conversion to be directly measured. Now at the beginning of its third year, the SAFE Project is already yielding results of direct relevance to tropical conservation and plantation management. As well as a core team of nearly thirty researchers and research assistants working full-time on the project, SAFE has also provided a platform for collaborative scientists studying a wide range of taxa and ecosystem functions. To date over 90 researchers from 23 different institutions have been involved with research projects in the SAFE area. The SAFE Project provides a good example of the benefits of closer collaboration between stakeholders in the development of conservation initiatives and a more sustainable palm oil industry.

Introduction

- Agricultural land has expanded rapidly in the tropics, great money wise, not so great in terms of global diversity.
- Southeast asia is particularly bad!
- Palm Oil has lots of uses - and new ones are regularly found! (Biofuels etc.) so demand is only set to increase.
- Species are found in Oil Palm Plantations (particularly fragments)
- however most species found in oil palm are not what would have been there originally and of lower conservation value.
- loss in biodiversity is probably directly linked to ecosystem functioning (pollination, pest control, decomposition, carbon sequestration) and loss of resilience/stability
- there is a need to understand how landscapes can be managed to maintain biodiversity and also sustainable crop production
- What is the optimal size and placement of fragments?
- land sharing vs land sparing

- areas of natural habitat could provide some functions for agriculture

Objectives

1. describe the rationale of SAFE
2. describe key achievements to date
3. highlight importance of close collaboration between industry and research
4. introduce future plans

Materials & Methods

Rationale

- Multidisciplinary
- Inform sustainable land-management practices
- has funding for enough time to research temporal aspects
- on a scale appropriate for its aims (i.e. Massive!)
- researchers from loads of different institutions

Project Design

- Sampling points across a landscape gradient
  - Primary Forest
  - logged forest to remain forested
  - logged forest earmarked for conversion
  - existing oil palm plantation
- in each area a range of fragments will be maintained (1ha, 10ha 100ha) in six replicate blocks

Results

- lots of initial data on forest quality
- definitions of poor/ok/good etc...

Global Consequences of Land Use (Foley 2005)

Abtract

Land use has generally been considered a local environmental issue, but it is becoming a force of global importance. Worldwide changes to forests, farmlands, waterways, and air are being driven by the need to provide food, fiber, water, and shelter to more than six billion people. Global croplands, pastures, plantations, and urban areas have expanded in recent decades, accompanied by large increases in energy, water, and fertilizer consumption, along with considerable losses of biodiversity. Such changes in land use have enabled humans to appropriate an increasing share of the planet's resources, but they also potentially undermine the capacity of ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality, and ameliorate infectious diseases. We face the challenge of managing trade-offs between immediate human needs and maintaining the capacity of the biosphere to provide goods and services in the long term. 60s

The Rest

- while land-use practices vary across the world, their consequences are the same - acquisition of resources for immediate human needs at the expense of degrading environmental conditions.
- affects everything
  - climate
  - carbon cycle
  - hydrology
  - nutrients in biosphere
  - biodiversity
  - etc.
- its a catch 22, we need the land use to provide us with stuff we need/want but we need ecosystems to survive too! **Food**
  - Croplands and Pasture cover 40% of the worlds land surface, rivalling forest cover
  - grain production has doubled since the 1960s
  - fertilize use has skyrocketed! - Very band for water quality
  - soil erosion, decreased fertility, overgrazing
  - in short: Short-term increases in food production are leading to long-term losses in ecosystem services

  Freshwater Resources (NA)

  Forest Resources

  - net loss of *alot* of forest in the last few centuries
  - managed lands replacing *natural* forest
  - things such as forest grazing and road expansion can have a significant impact without changing forest area.
  - introduction of pests
  - reforestation is also a thing!
  - the biomass of European forests has increased by 40% while the area has remained similar.

  Confronting the Effects of Land Use

  - we need good policy!

How will oil palm expansion affect biodiversity? Fitzherbert et al. (2008)

Abstract

Oil palm cultivation is frequently cited as a major threat to tropical biodiversity as it is centered on some of the world's most biodiverse regions. In this report, Web of Science was used to find papers on oil palm published since 1970, which were assigned to different subject categories to visualize their research focus. Recent years have seen a broadening in the scope of research, with a slight growth in publications on the environment and a dramatic increase in those on biofuel. Despite this, less than 1% of publications are related to biodiversity and species conservation. In the context of global vegetable oil markets, palm oil and soyabean account for over 60% of production but are the subject of less than 10% of research. Much more work must be done to establish the impacts of habitat conversion to oil palm

plantation on biodiversity. Results from such studies are crucial for informing conservation strategies and ensuring sustainable management of plantations.

Introduction

- palm oil has grown to be ubiquitous (need synonym!) in the food and chemical industry (soap etc.)
- this has led to a significant increase in the space that is used to grow it!
- as a tropical crop its production is generally centred in highly biodiverse localities (Malaysia and Indonesia are the biggest producers) with high levels of endimism - (Basiron 2007)
- new uses of palm oil being investigated - may lead to even more growth in production
- they want to look at how much research is actually being done on the impacts of palm cultivation

Methods

- they used Web of Science looking for "“palm oil” or “oil palm”"
- 3056 publications between 1970 and 2006, were categorised based on title, abstract and key words
- compared with “agriculture” and "“vegetable crop name” & “oil”"

Results and Discussion

- palm oil oil and soybean contribute 60% of global production of vegetable oil but only 10% of the research interest
- very low number of the publications look at biodiversity (0.75%) or even environmental issues of palm production (2.06%)
- those that do look at biodiversity look at large mammals and birds
- management to enhance biodiversity is not neccessarily contrary to increased oil production (it might reduce soil erosion and flooding for example)

Oil Palm Research in Context: Identifying the Need for Biodiversity Assessment (Turner et al. 2008)

Abstract

Oil palm is one of the world’s most rapidly increasing crops. We assess its contribution to tropical deforestation and review its biodiversity value. Oil palm has replaced large areas of forest in Southeast Asia, but land-cover change statistics alone do not allow an assessment of where it has driven forest clearance and where it has simply followed it. Oil palm plantations support much fewer species than do forests and often also fewer than other tree crops. Further negative impacts include habitat fragmentation and pollution, including greenhouse gas emissions. With rising demand for vegetable oils and biofuels, and strong overlap between areas suitable for oil palm and those of most importance for biodiversity, substantial biodiversity losses will only be averted if future oil palm expansion.

Oil palm: one of the world’s most rapidly expanding crops

- agricultural intensification is a significant threat to biodiversity and vegetable oils are some of the fastest growing agricultural commodities

- Malaysia and Indonesia contribute 80% of global production
- the impact of palm oil on ecology is directly related to the amount of deforestation which it likely causes deforestation (debated amoung scientists and industry)
- and the biodiversity value of tropical forest vs that of palm oil plantations

Contribution of oil palm expansion to deforestation

- it is very difficult to quantify with poor data and complex causes of land-cover change
- four ways in which oil palm expansion could contribute to deforestation:
  1. primary motive for clearance
  2. replacing previously degraded forest
  3. as a combined economic enterprise with timber etc.
  4. indirectly through generating improved road access to previously inaccessible forest
- it is therefore pretty easy to misjudge how the oil-palm came to be there, it may not have directly replaced pristine forest
- **Malaysia:** first commercial plantation in 1917 - expanded to Sabah and associated with logging - Expansion of 1.8 million ha between 1990-2005 (while 1.1m ha were lost)
- **Indonesia:** commercial plantations from 1911 but expansion beyond Sumatra not till the 1980s. Some crap loopholes mean that timber/pulp companies can log forest under the pretence that they will plant but then never do... And illegal plantations pop up in protected areas. Conversion to oil plantation could account for 16% of deforestation between 1990 and 2005 - but this estimate has very high uncertainty and could very well be an under or over-estimate
- while its historical contribution to deforestation is uncertain, its future potential is significant!

Effects of converting forests to oil palm plantations

- two possibilities:
  1. palm oil cannot sustain the same biodiversity as forest and so the priority should be to reduce deforestation
  2. plantations can be managed so they can sustain the same forest species while maintaining high yields. In which case we should focus efforts into enhancing this biodiversity at plantations
- they did a literature review to assess this...
- palm plantations are structurally less complex than natural forest with uniform tree ages, lower canopy, sparse undergrowth, a less stable microclimate and greater human disturbance
- palm is also cleared and replanted on a 25-30 year rotation
- **Species Richness:** Palm had consistently fewer than half as many vertebrate species as forest while invertebrates were more variable
- across all taxa only 15% of species in primary forest were also found in oil palm plantations
- **composition:** large differences in faunal species between palm and forest. Not a random subset, specialised diets, reliant in forest habitat features (i.e. canopy), small range sizes, high conservation concern.
- plenty of caveats as to why these are likely conservative estimates
  - harder to detect species in forest (complex and canopy)
  - transient species in forest edges coming into plantation
  - lag between habitat loss and extinction

Comparison with other land uses

- oil palm is a poor substitute for forest - even degraded forest and has worse species richness than most other agricultural alternatives (i.e. rubber)

Landscape scale effects

- palm plantations can act a a barrier to movement/migration
- forest fragments in oil plantation supported fewer than half the ant species as nearby continuous forest
- fragments also have more ’tramp’ species (invasive species)
- fragmentation also massively increases the number of forest edges

What can be done to mitigate the impacts?

- we need good policy!
- strategies for land allocation - put plantations in already shit land
- planters need to now where they will cause the least ecological damage!

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