

# Téledétection de l'évolution des forêts au Népal

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# Enjeux variés de la forêt

Déboisement (enjeux agricoles), dégradation : source de carbone.

Puits de carbone terrestre : environ  $\frac{1}{4}$  des émissions anthropiques de carbone est absorbé.

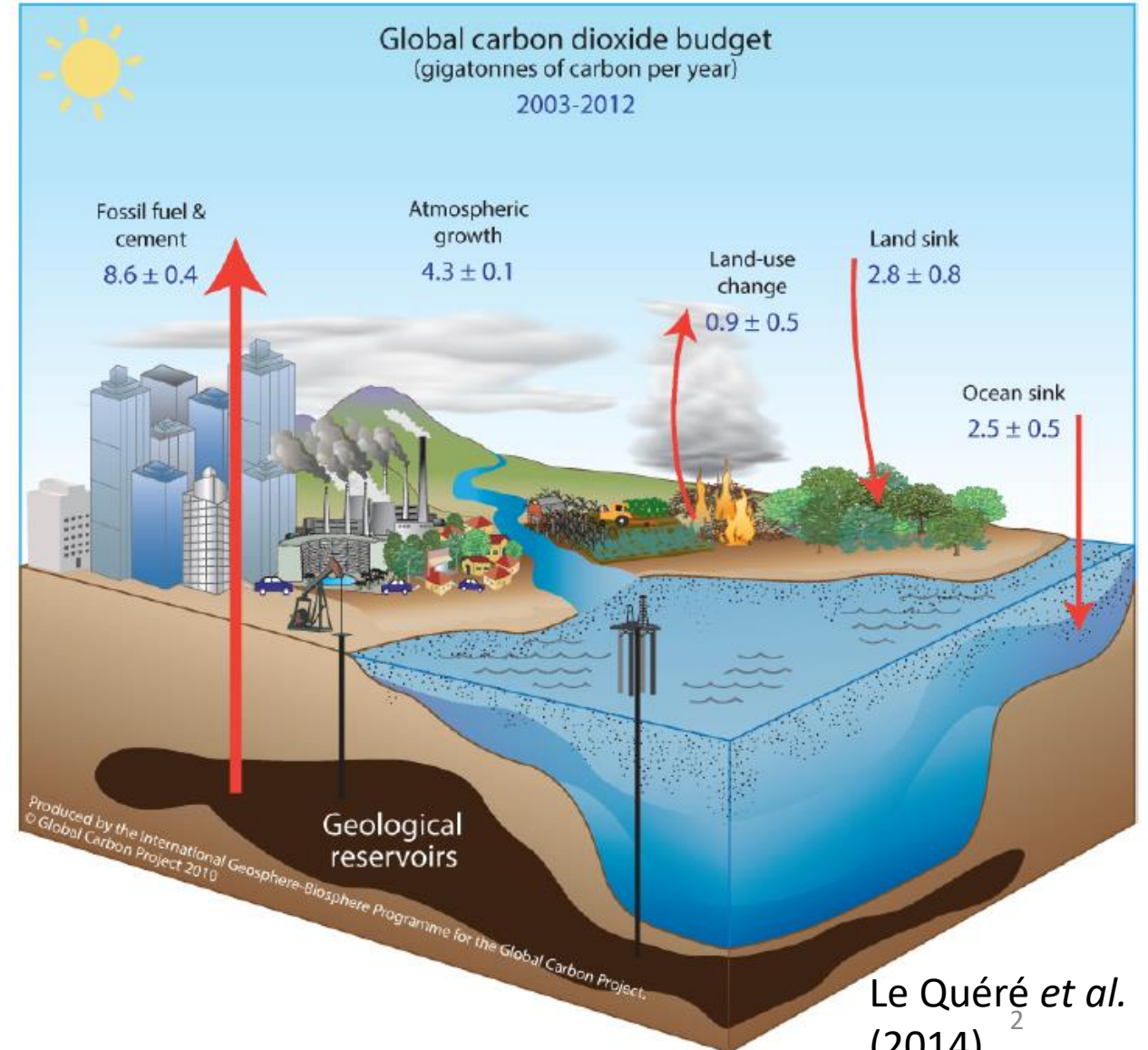
Bois : source d'énergie du quotidien.

Connexion avec des enjeux de biodiversité et hydrologiques.

## Besoins :

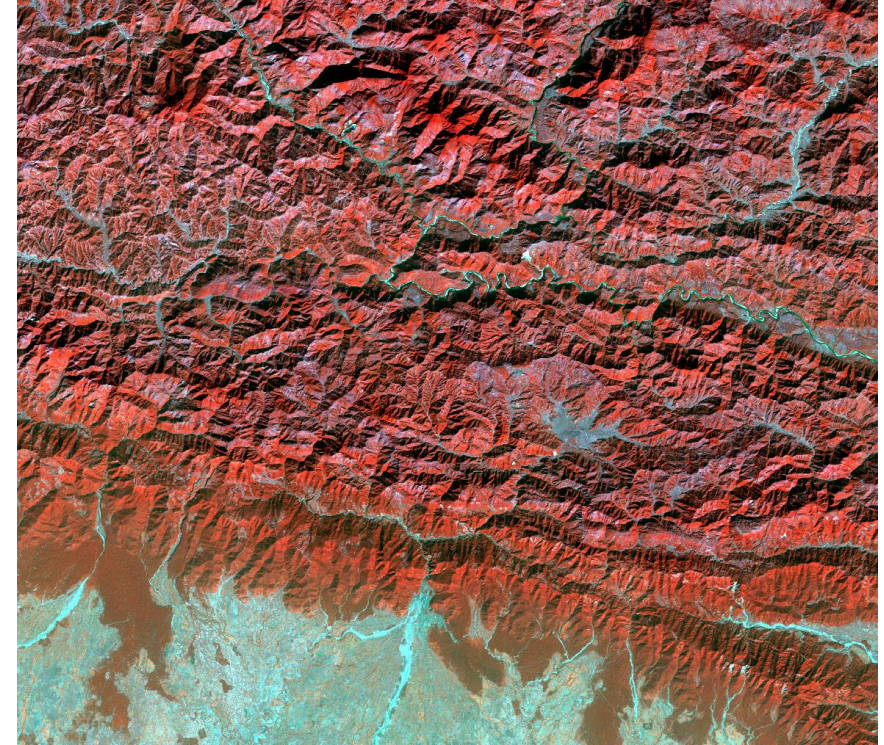
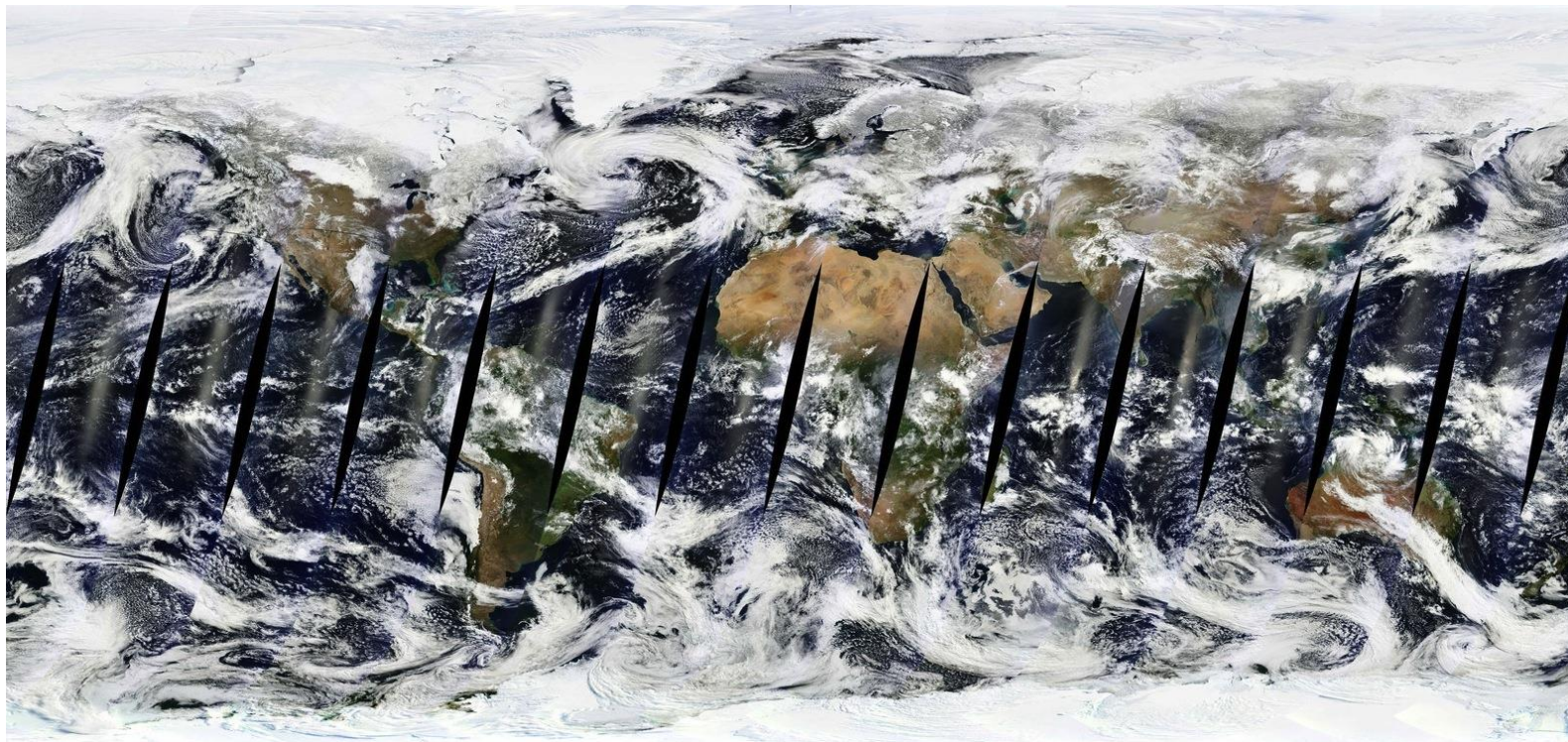
- Suivi fonctionnel. Ex : Phénologie de la végétation boréale, variable essentielle pour la productivité (Sibérie)
- Suivi structurel (couverture, densité, biomasse...) Ex : **Suivi de l'effet de modalités de gestion forestière (Népal)**

Télédétection à des échelles variées + approche interdisciplinaire.

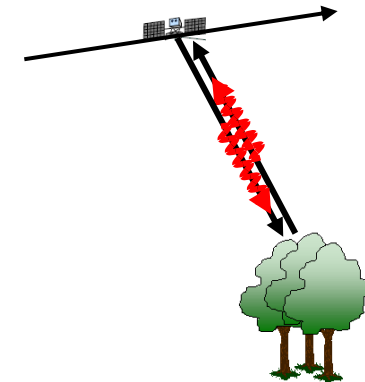


Le Quéré *et al.*  
(2014)<sup>2</sup>

# Téledétection à différentes échelles et à différentes fréquences de revisite



Variables fonctionnelles (phénologie) et structurelles (couverture forestière, densité)



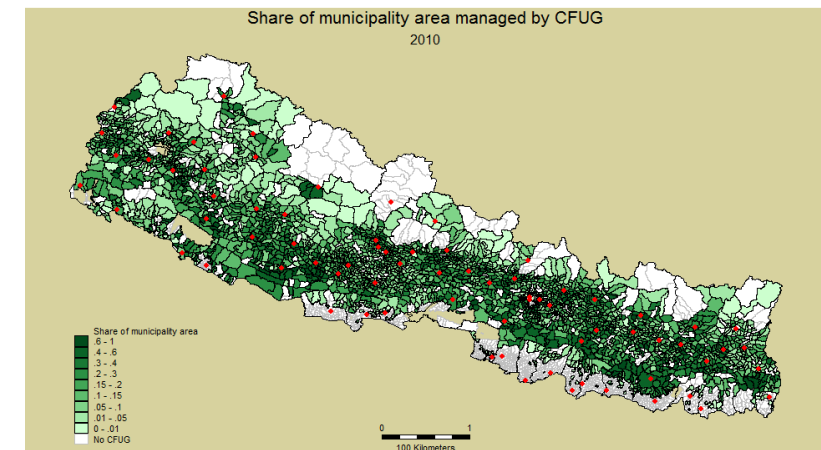
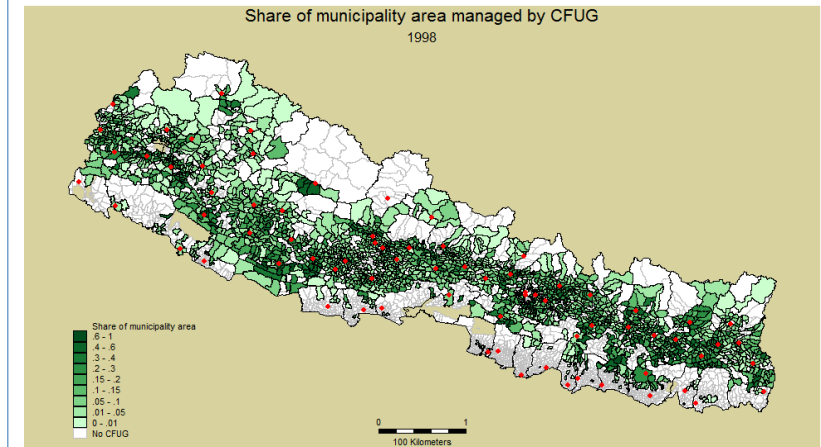
# Télédétection et gestion forestière au Népal

- Déclin de la forêt Durant les années 1970 et 1980. En 1999, la forêt couvre 5.83 millions ha, 39.6% de la surface du pays.
- 1990 : Gouvernement népalais instaure un programme de delegation de la gestion forestière. **Community Forest User Groups (CFUGs)** .

→ Accès restreint aux ressources forestières aux membres du CFUGs. Droit de collecte de bois régulé (ex : **bois de chauffe**, fourrage). Droit de pâturage limité.

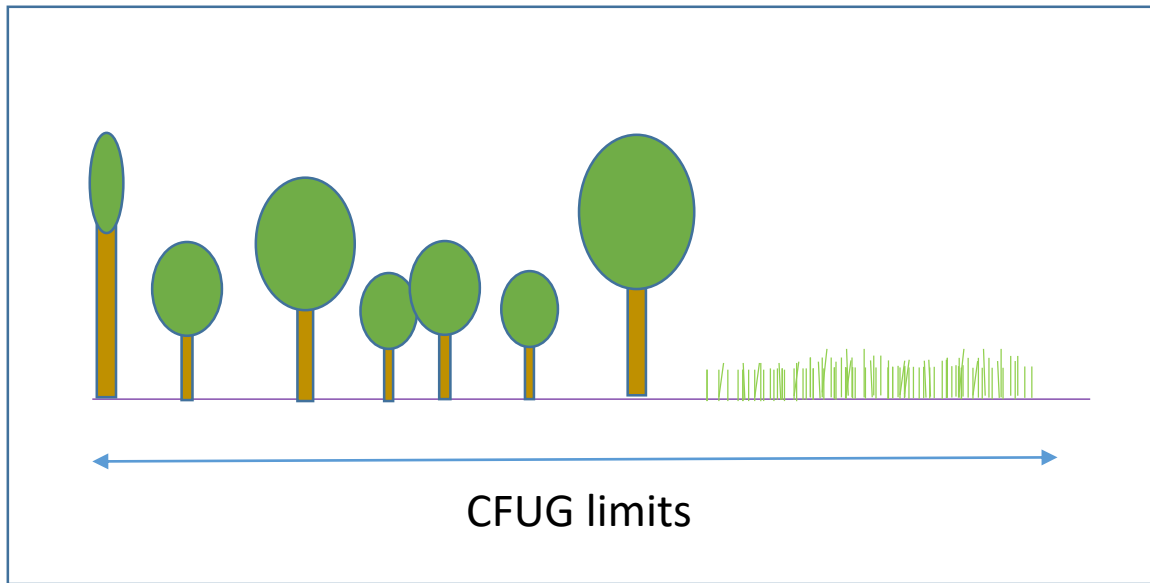
→ Objectif de régénération forestière et de redistribution locale des produits de la forêt.

18000 CFUGs ont été créés, sous la supervision des Districts Forest Offices.

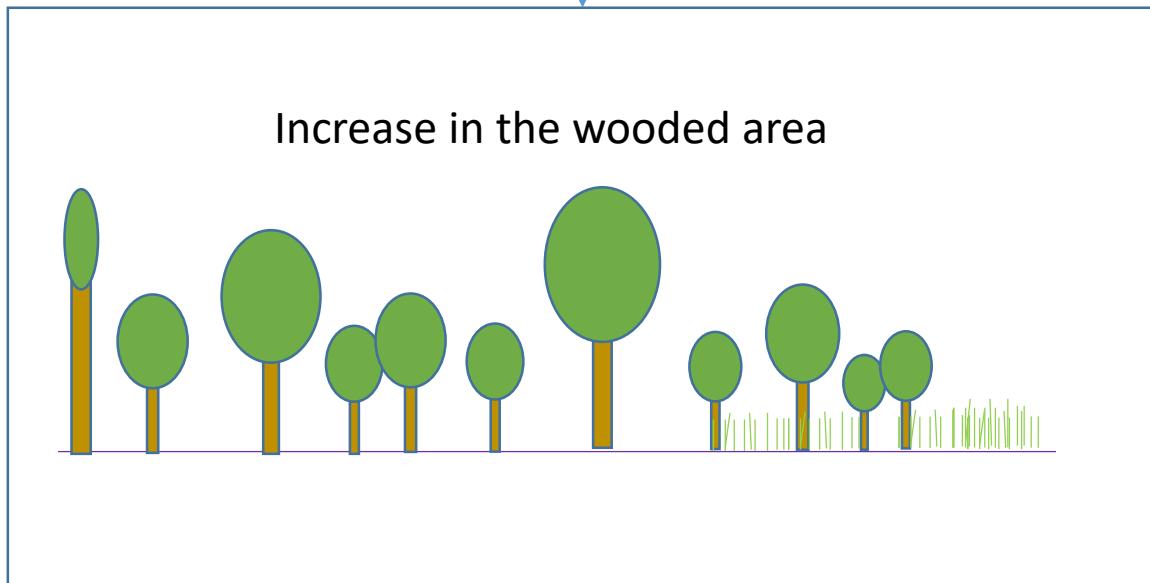


ANR GolFor DeepN. Objectif : analyser le fonctionnement et les résultats du programme de CFUGs, sur la forêt et sur la société. Télédétection : évolution de la forêt.

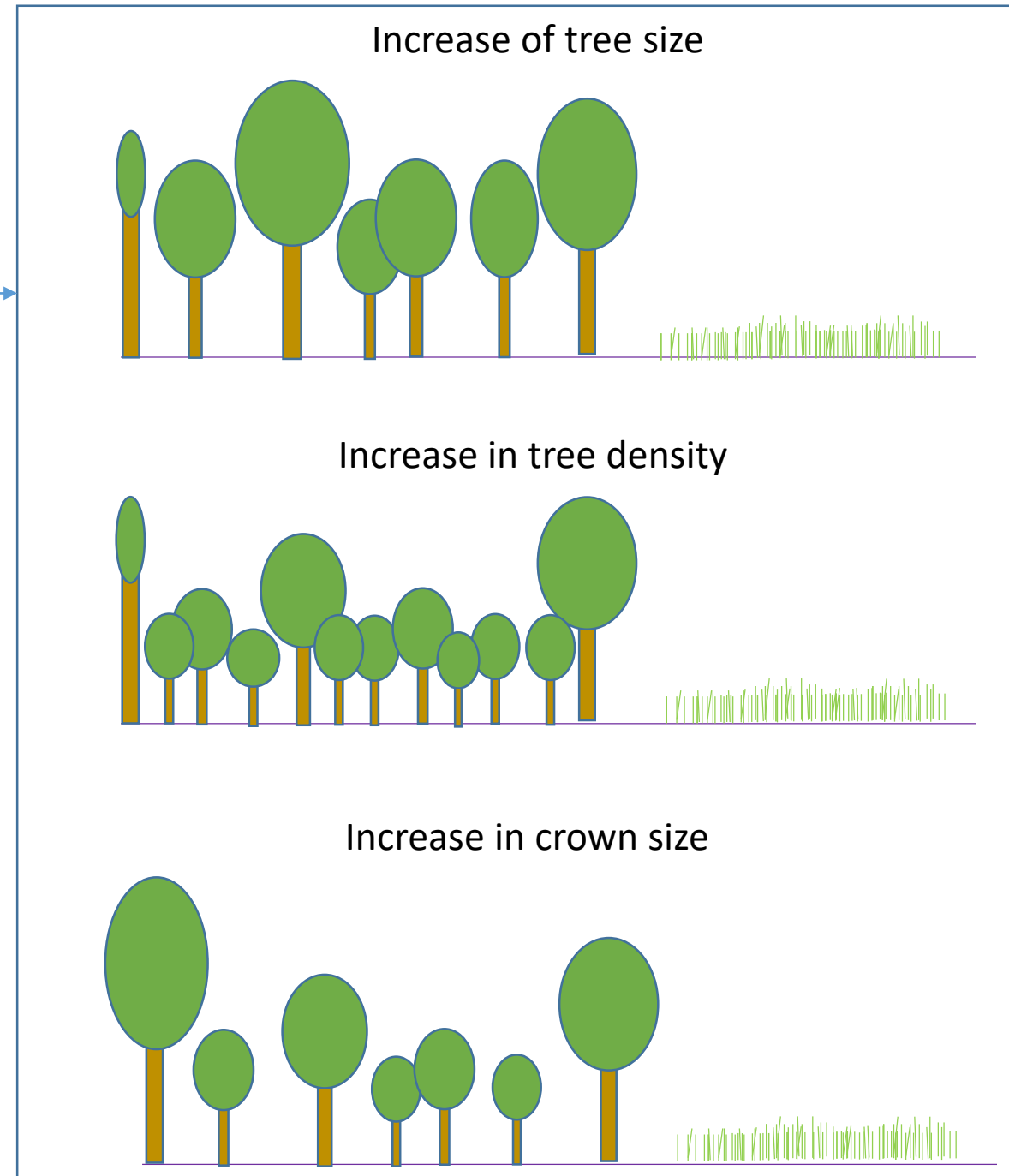
F. Libois (Ecole d'Economie de Paris). J. Smadja, O. Aubriot (CEH). JM Baland (Namur). Etudiants : S. Luon, Thang Le



### Cartographie de la couverture forestière



### Croissance de la biomasse



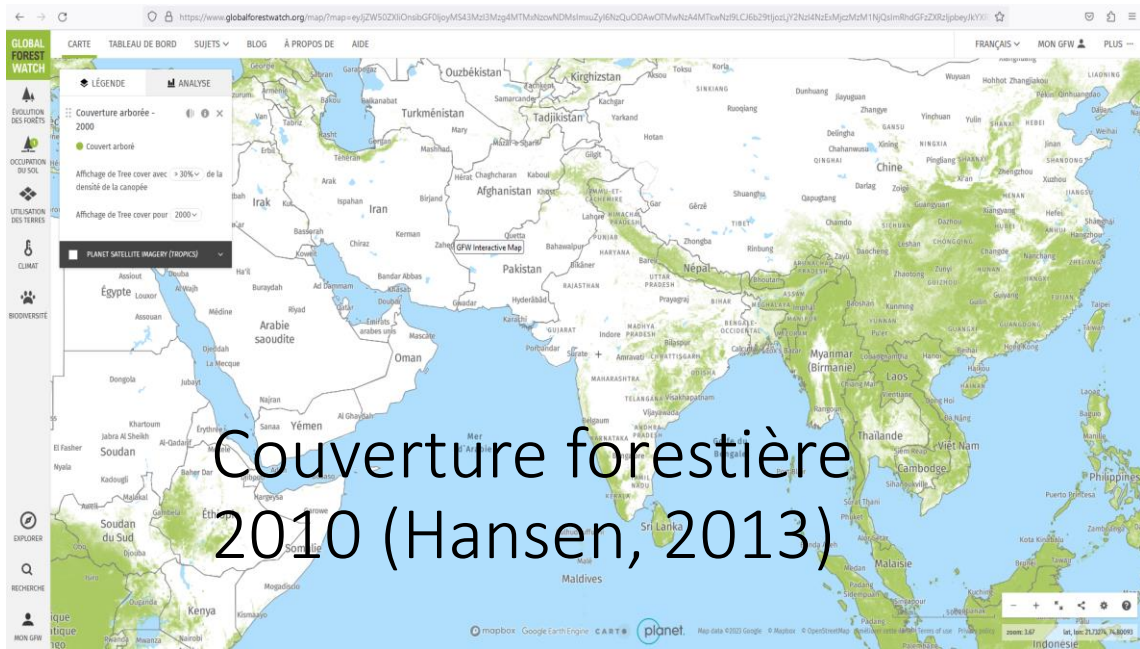
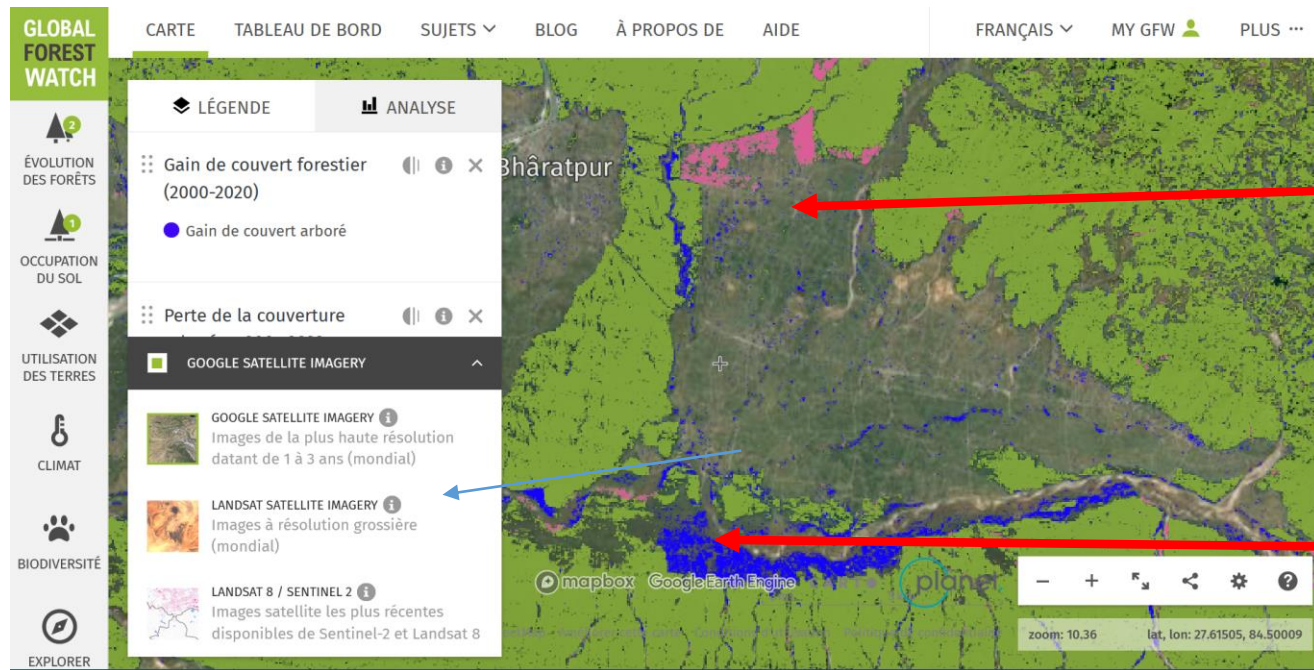
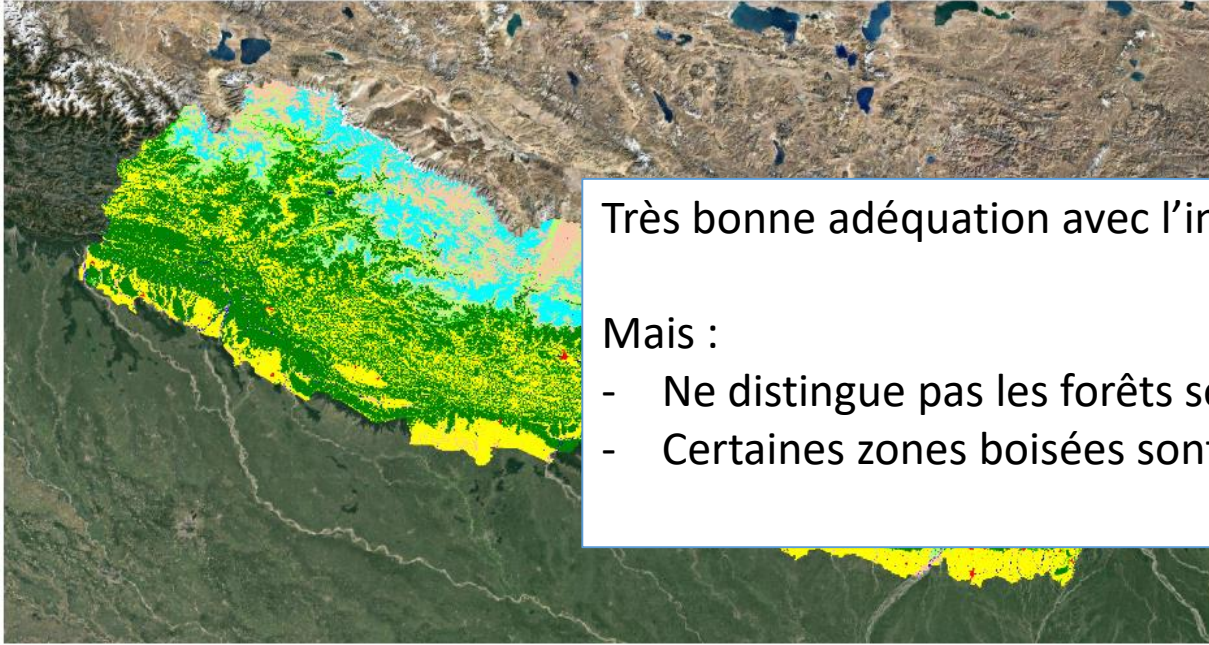


Photo by F. Libois



# Cartes d'occupation du sol ICIMOD



Très bonne adéquation avec l'inspection visuelle.

Mais :

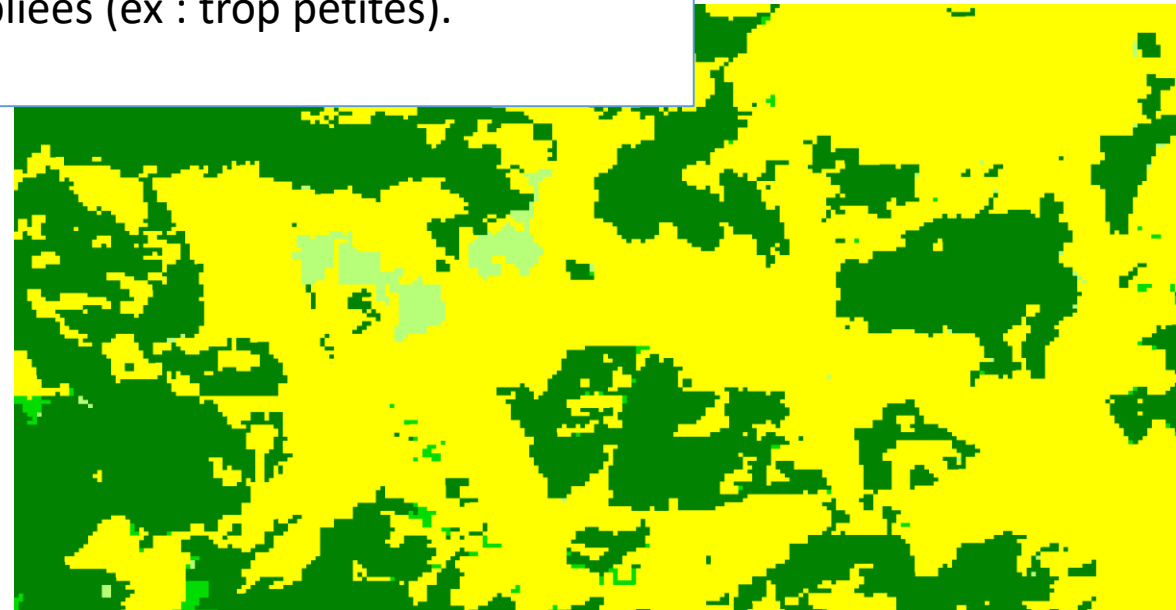
- Ne distingue pas les forêts selon leur densité
- Certaines zones boisées sont oubliées (ex : trop petites).

1990, 2000, 2010

30 m resolution spatiale

8 classes

Methode : Classification par objets, images landsat,  
Landsat, inspection visuelle.



# 2020

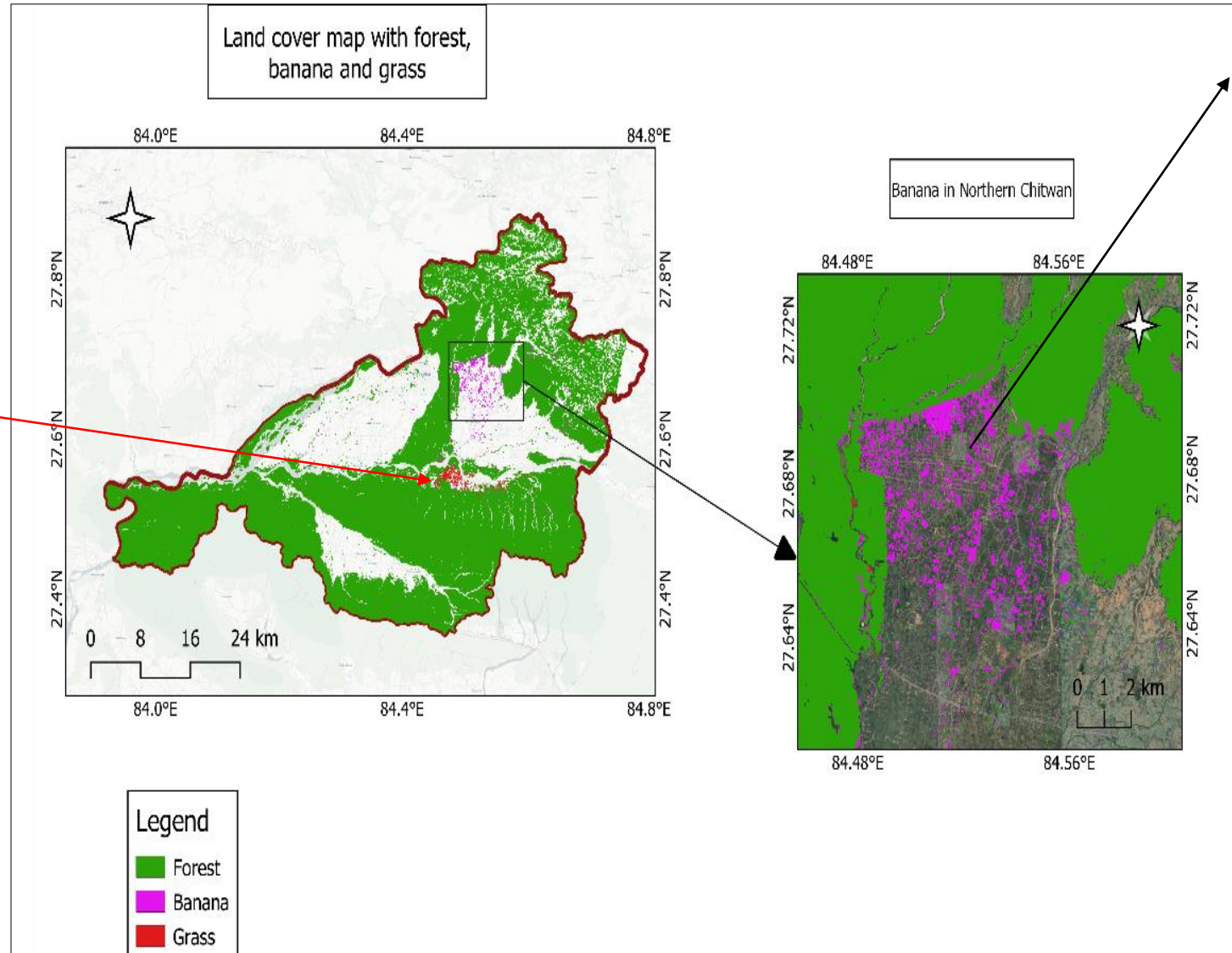
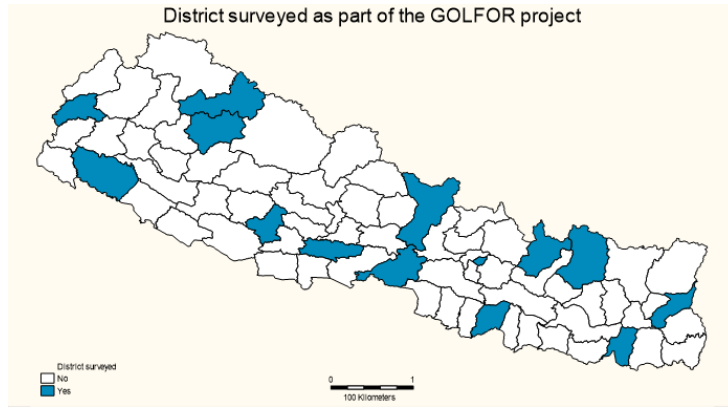


Photo by F. Libois

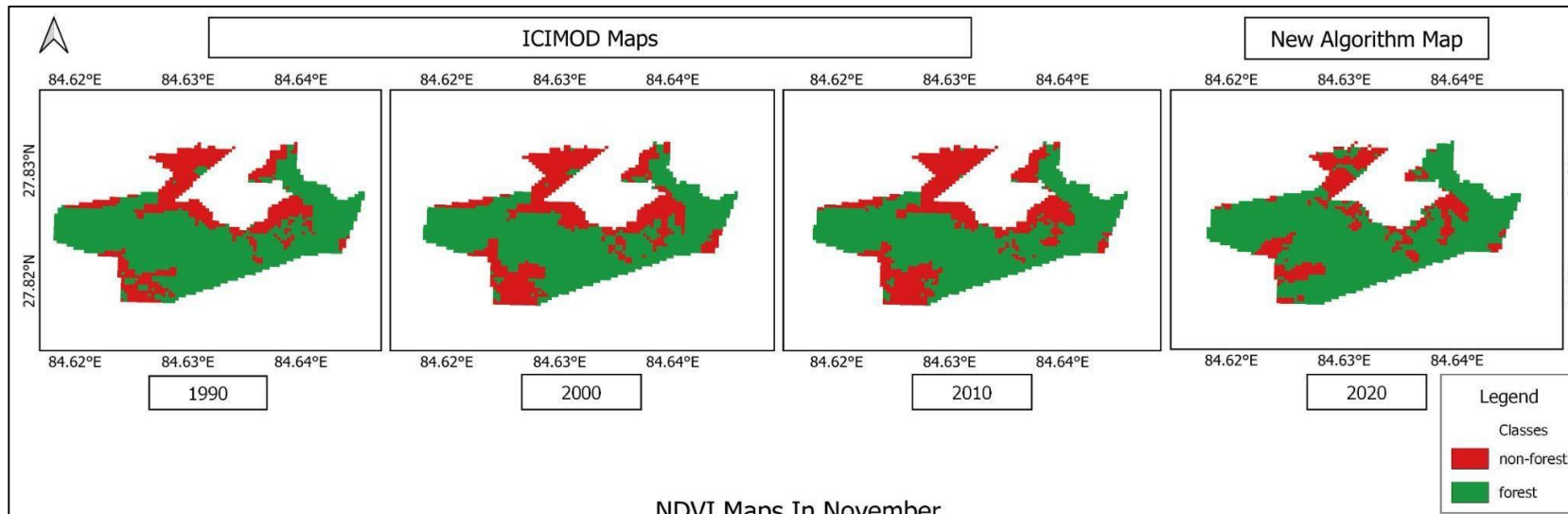
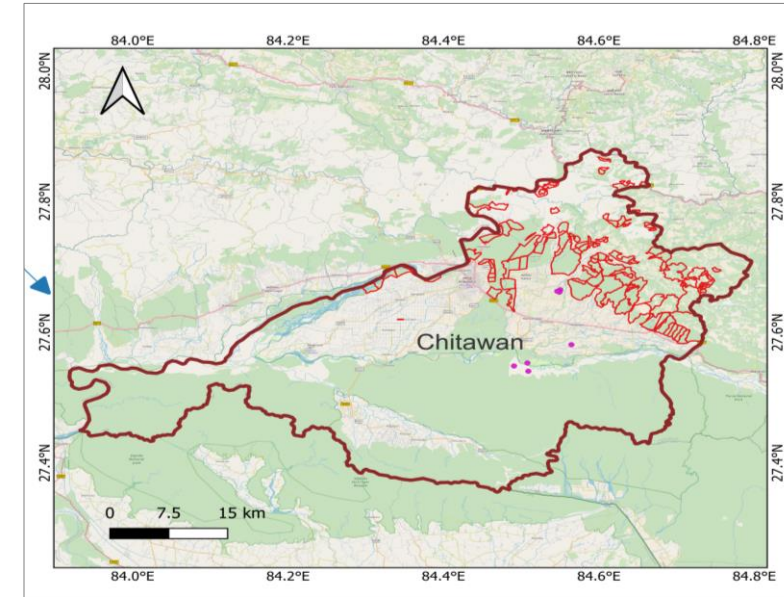
Thang Le Quang Internship. PhD Thesis starting in November.



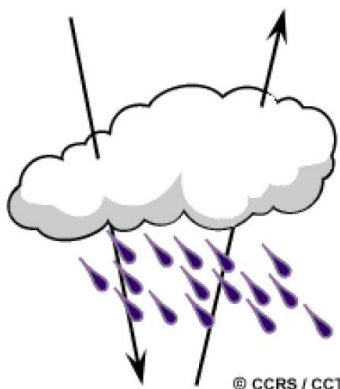
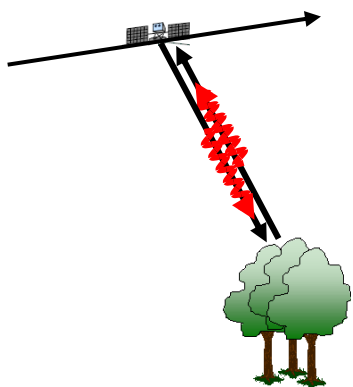
# Analyse : changement de couverture forestière dans les CFUG



Year	Area (km <sup>2</sup> )	Forest (km <sup>2</sup> )	Non-forest (km <sup>2</sup> )
1990	100000	50000	50000
2000	100000	45000	55000
2010	100000	40000	60000
2020	100000	35000	65000

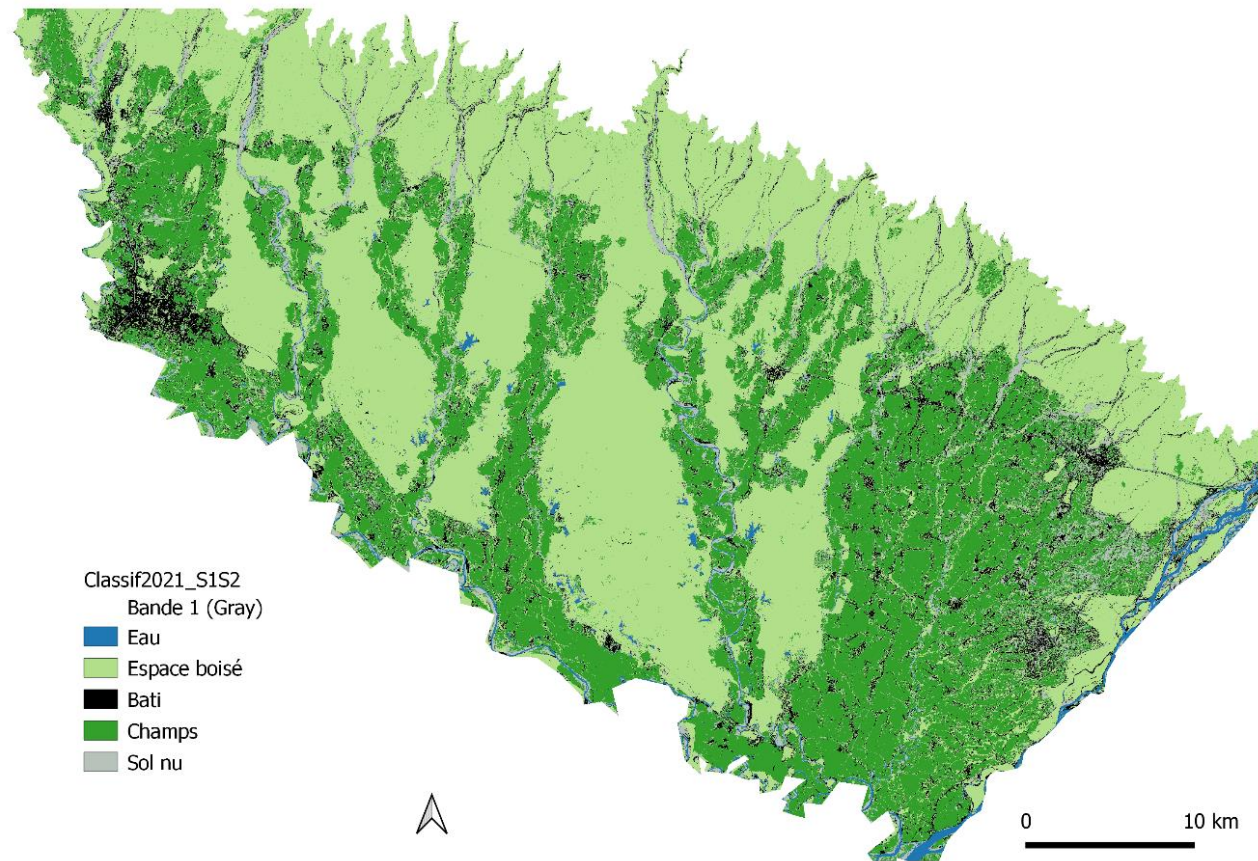
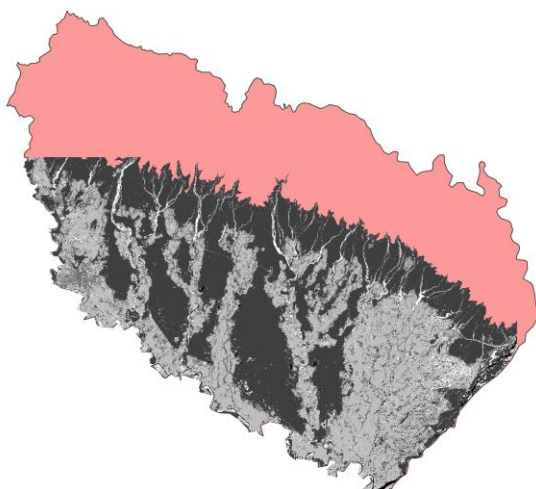
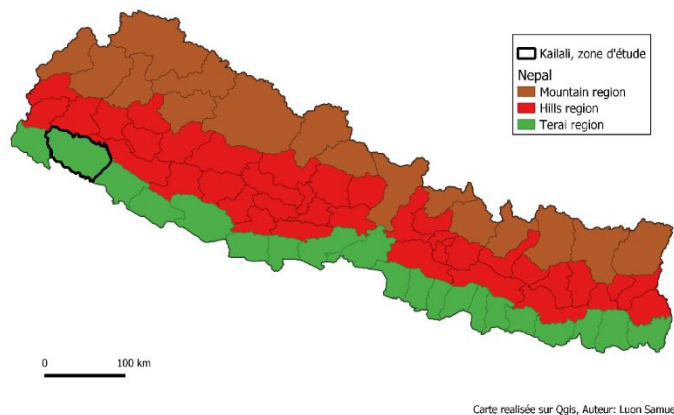


# Prototype 2 : Couplage radar / optique pour les plaines.

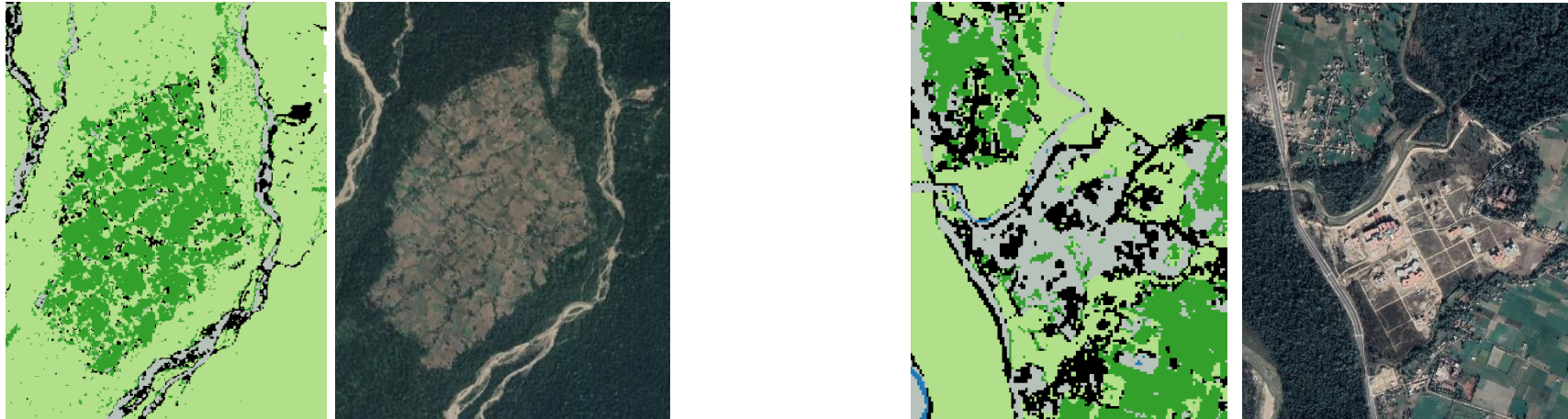


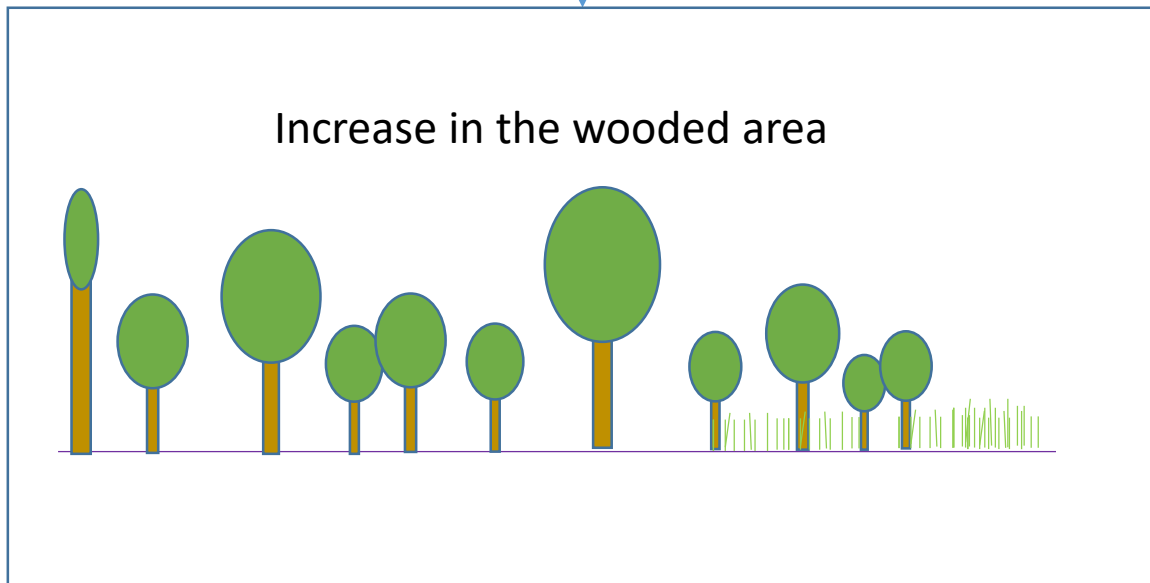
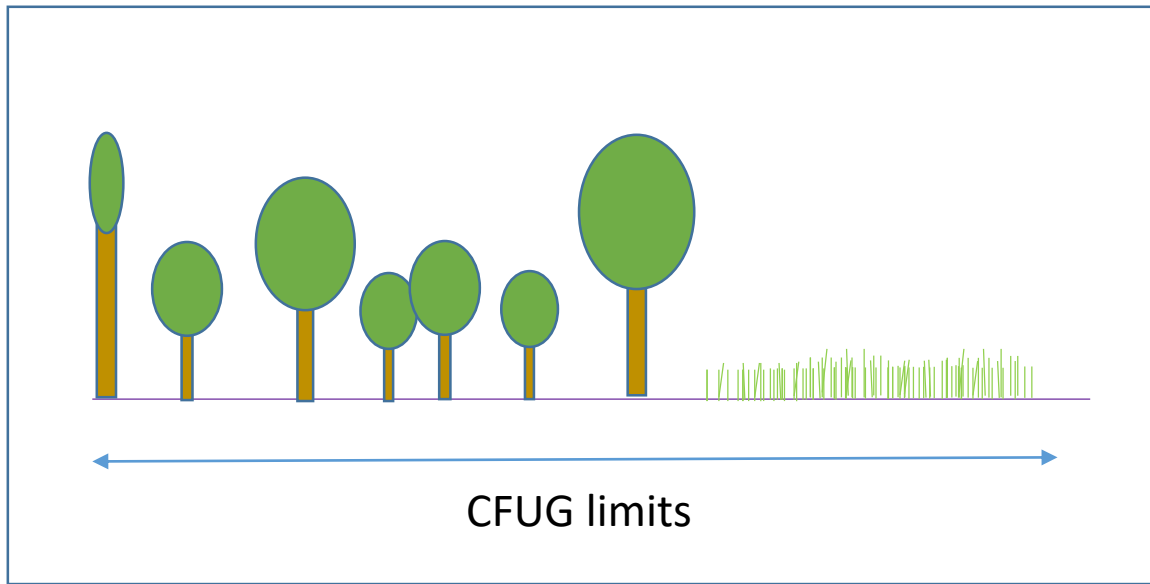
© CCRS / CCT

Division physique du Nepal

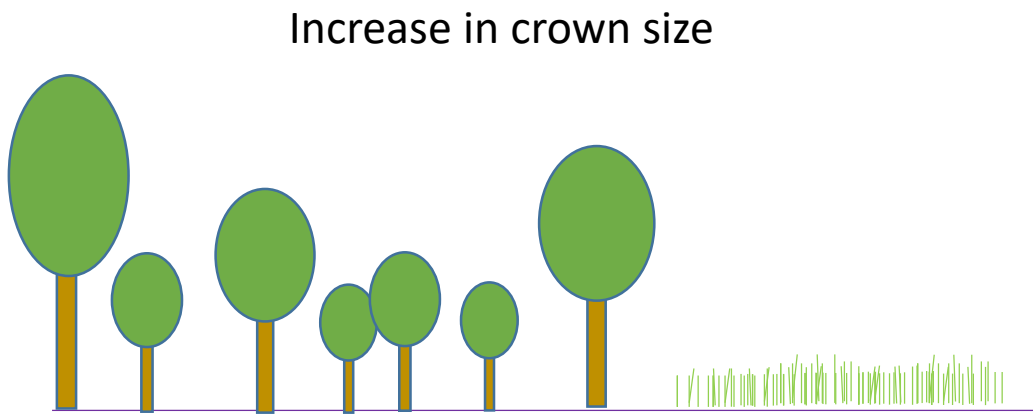


# Couplage radar / optique pour les plaines.



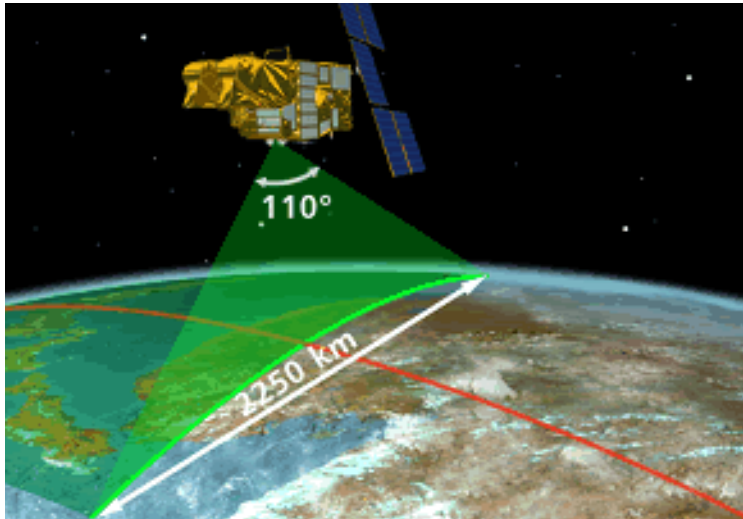


## Vegetation material density mapping



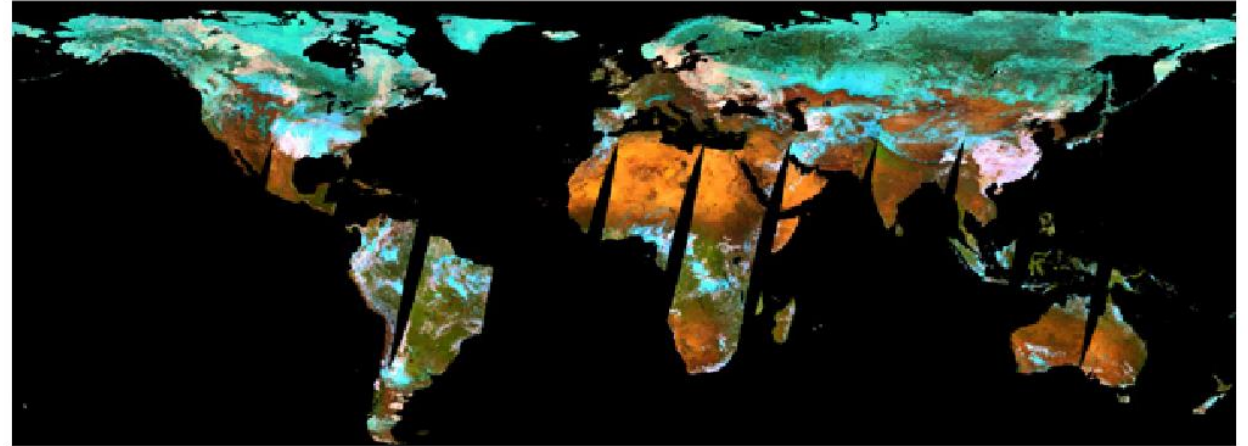
# SPOT-VEGETATION

Observations quotidiennes



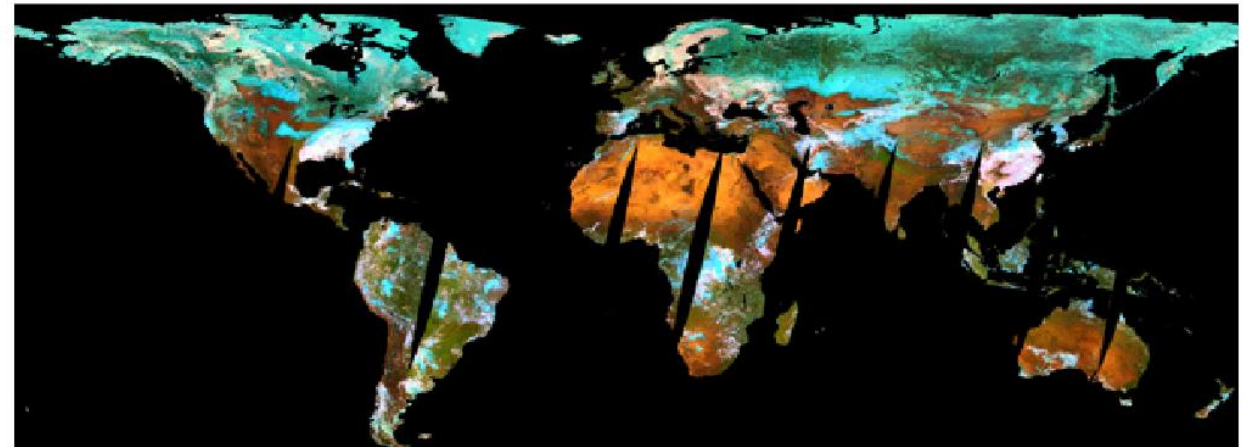
daily coverage

March, 13th 1999



daily coverage

March, 14th 1999



# Objectif 2 : densification

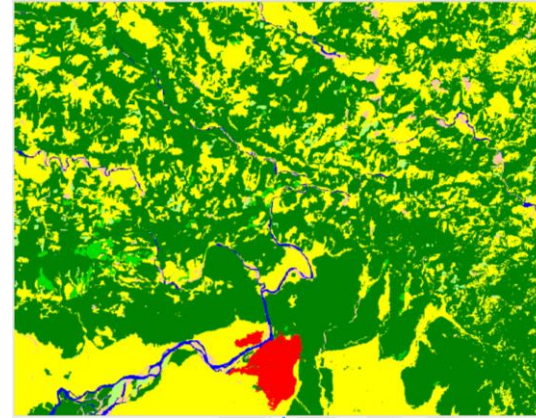
- Copernicus Leaf Area Index (LAI)
- BIOPAR Geo-V2 dataset. Baret et al. 2013, Camacho et al. 2013.
- Capteur SPOT-VEGETATION. **1km resolution spatiale.**
- **Une image tous les 10 jours (échelle mondiale), 1999-2013.**

Les LAI est il un bon indicateur de :

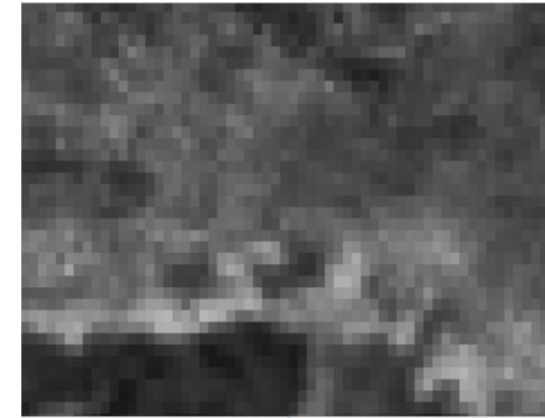
- La distribution spatiale des forêts?
- L'évolution temporelle des forêts?

Comment évolue le LAI avec l'établissement des CFUGs?

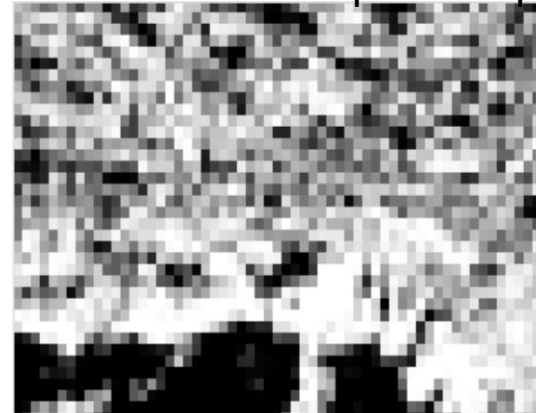
30 m Landcover map



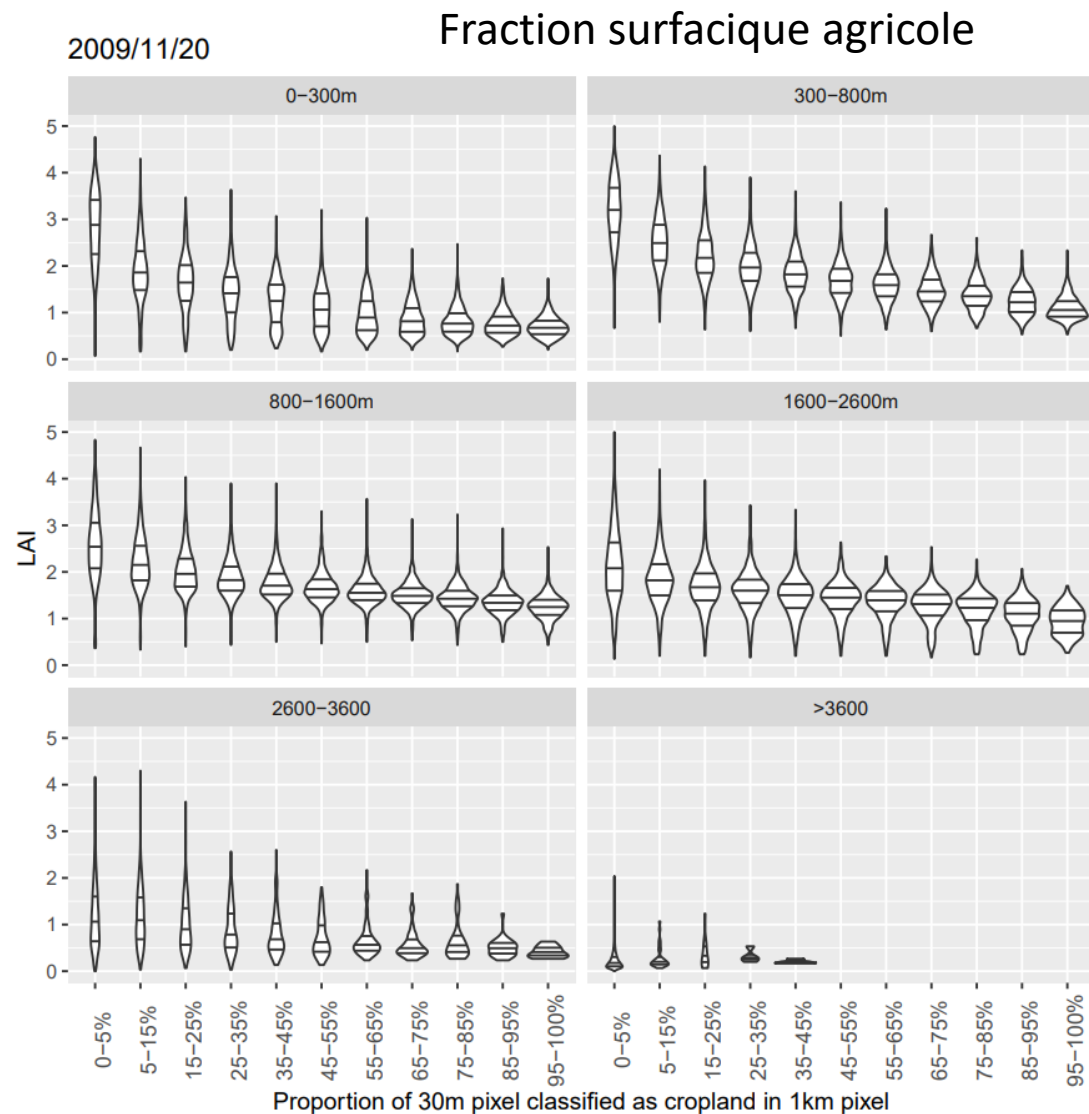
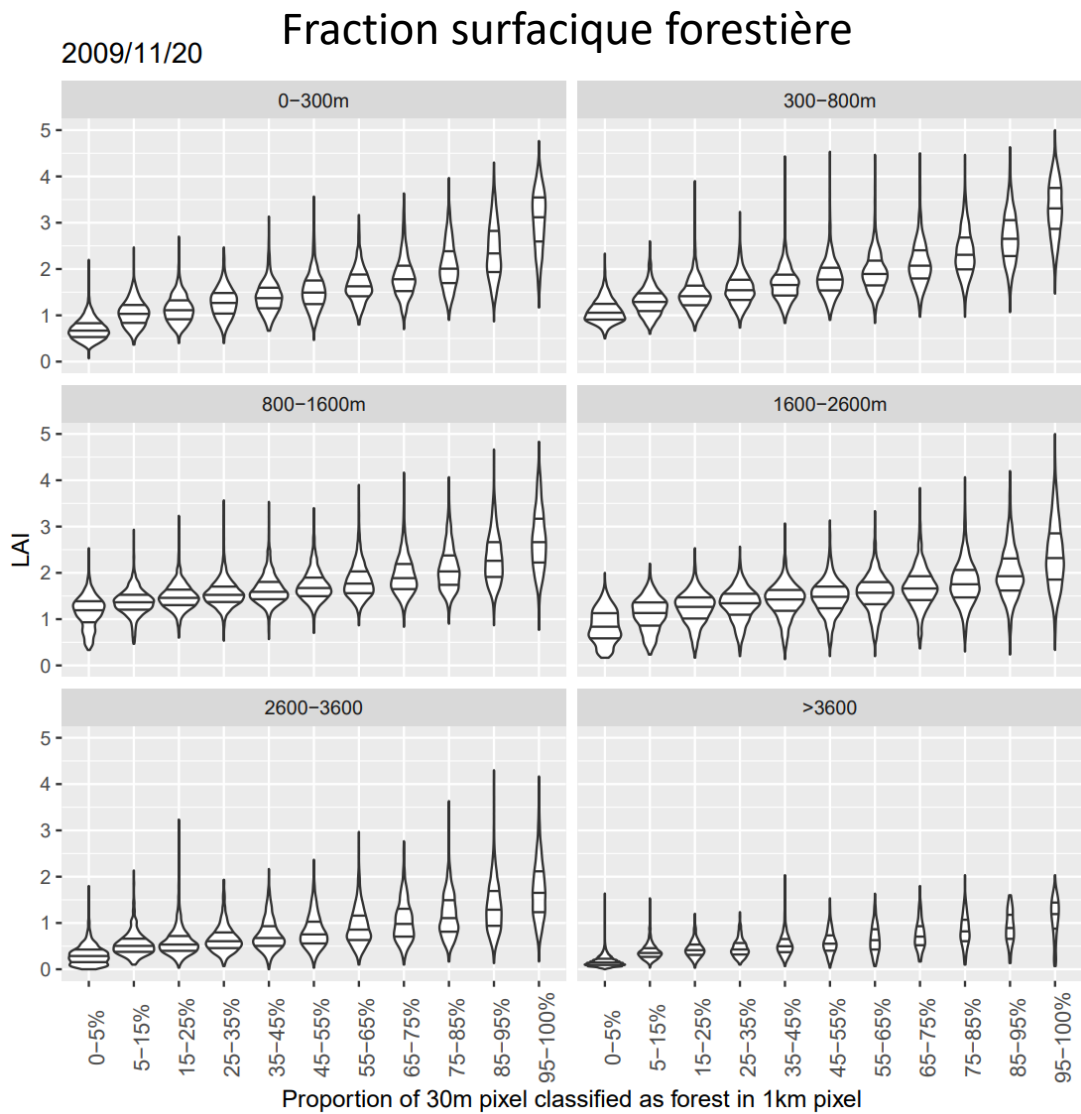
1km LAI



Proportion of the 1km pixel mapped as forest



# LAI de novembre

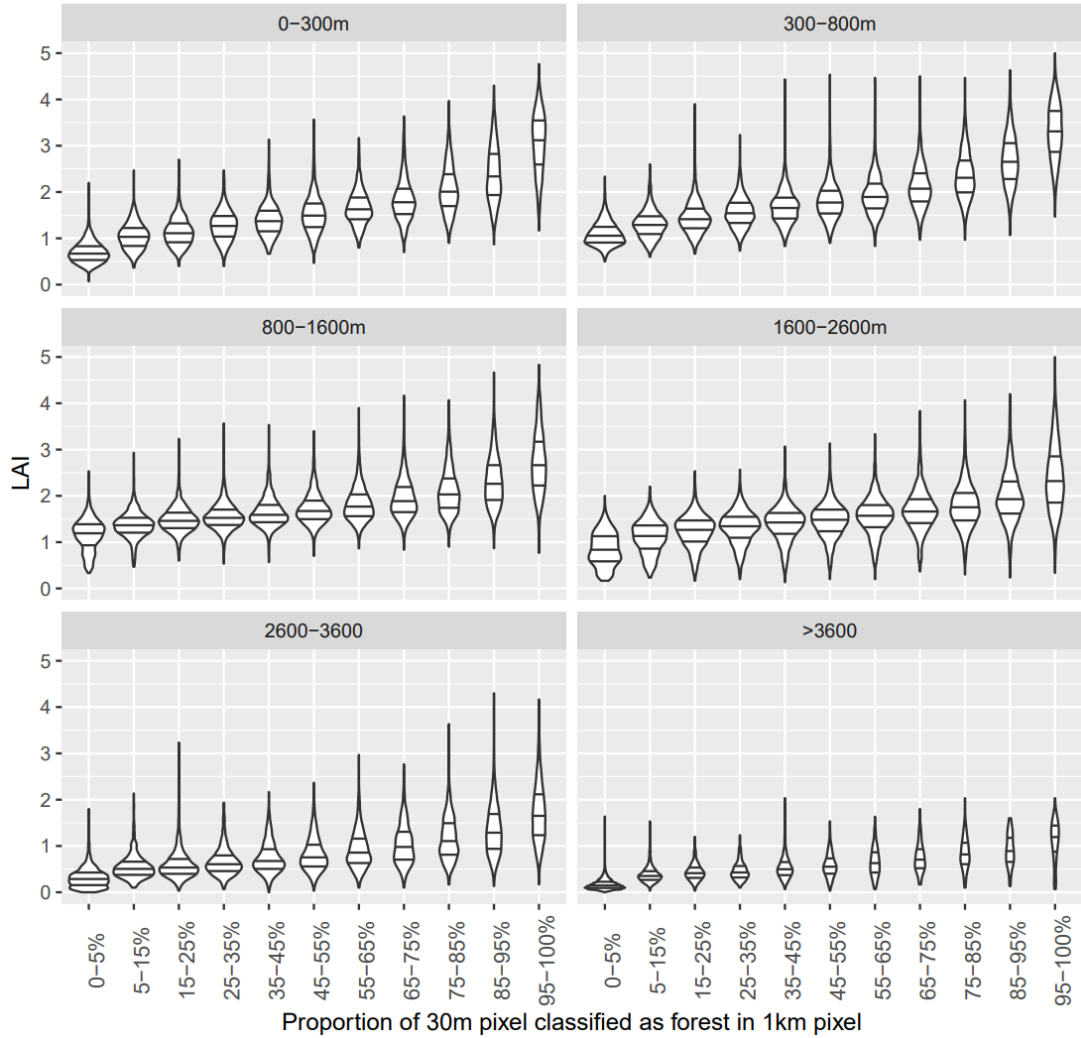


En novembre, la végétation verte est essentiellement forestière.

# November LAI against

## Forest fraction

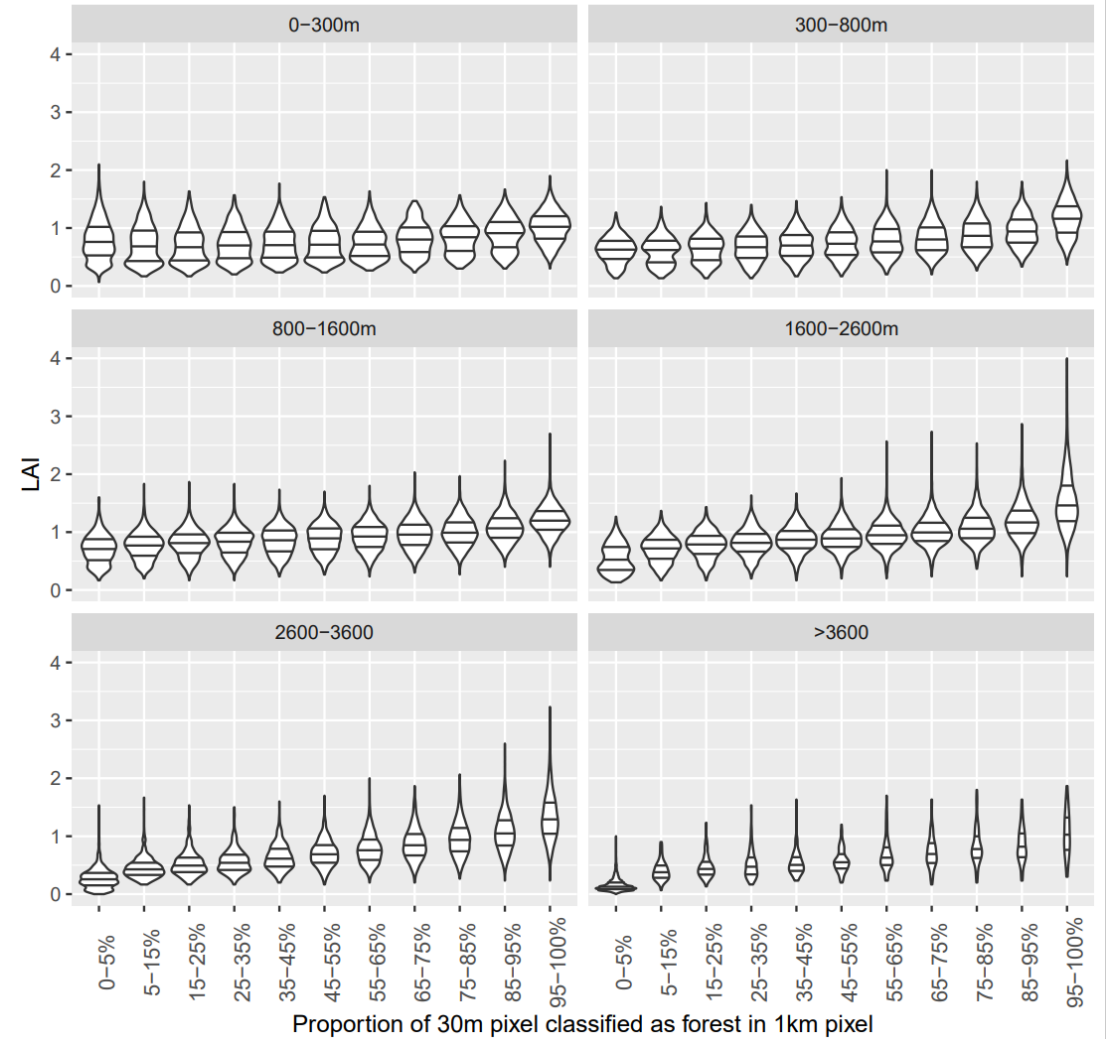
2009/11/20



# March LAI against

## Forest fraction

2012/03/20



In November, the « green » vegetation is almost only forests.



# LAI en fonction de la fraction forestière et de la fraction agricole

$$LAI_p^t = \alpha_0^t + \alpha_1^t \text{Forest fraction}_p^t + \alpha_2^t \text{Cropland fraction}_p^t + X_p^t B^t + \varepsilon_p^t \quad \text{for every } t$$

Forest land (46%) and cropland (35%) do constitute the main land cover classes of the country in 2010

controls include altitude, latitude and longitude

Reference category:

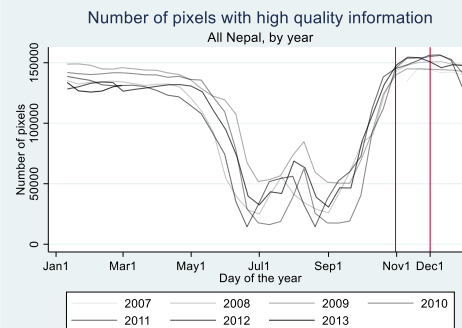
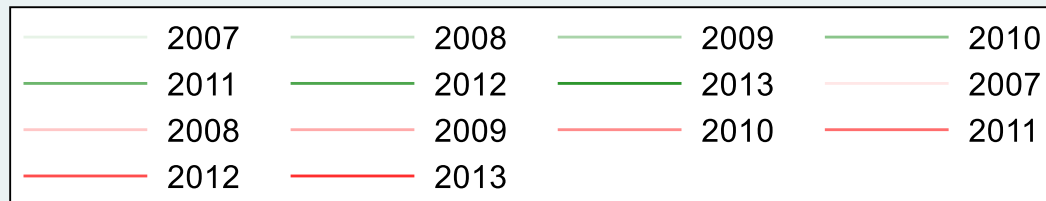
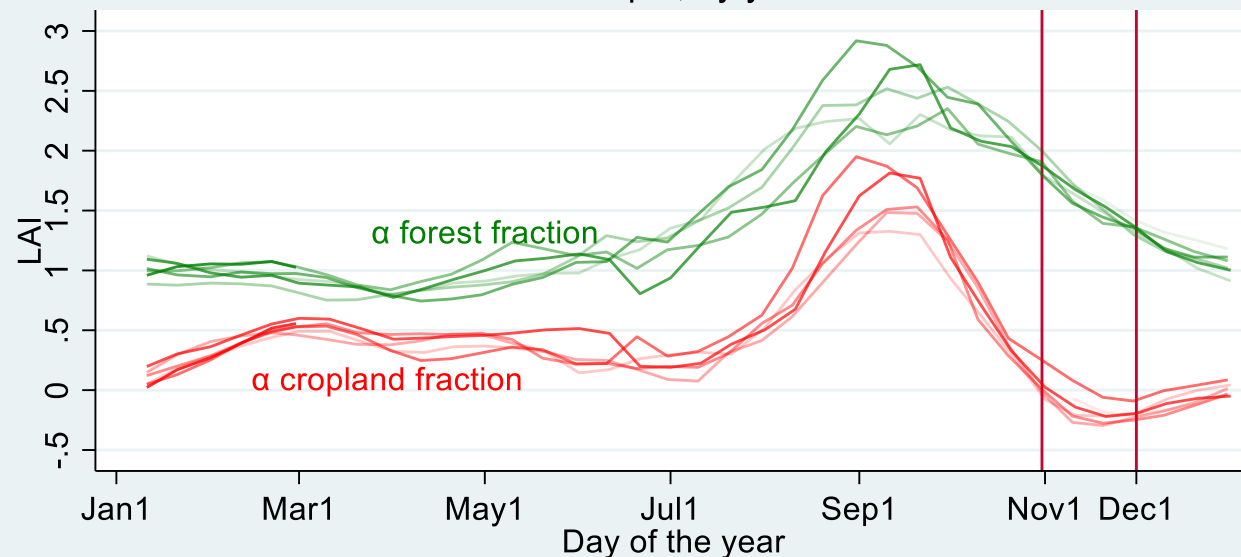
snow (1.3%), barren land (6%), water (.5%) buildup area (.5%), grassland (8%) and bushes (2%)

In November, converting a reference pixel in a pixel fully covered by forests increases the LAI by 1.5. A conversion to a pixel fully covered by cropland slightly reduces the LAI.

November is also the month where the gap between forest land and cropland is the largest. And also when information is the most reliable

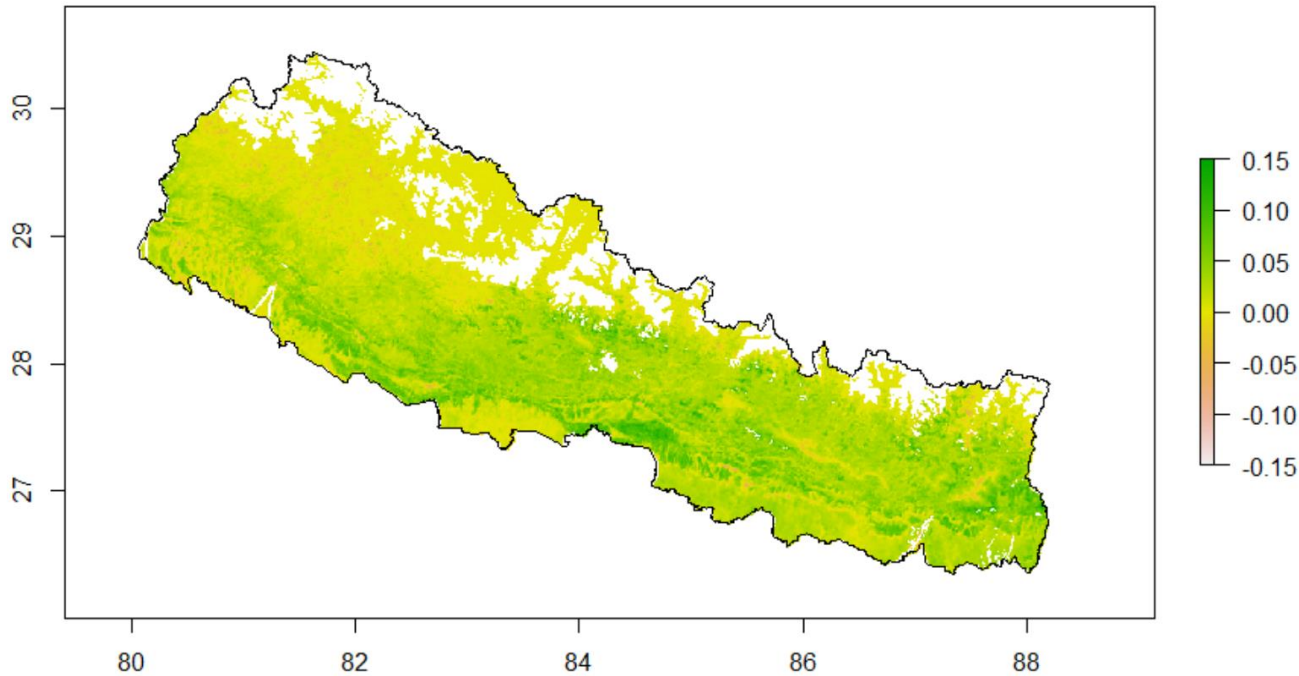
## Leaf Area Index as a function of forest and cropland fraction

All Nepal, by year



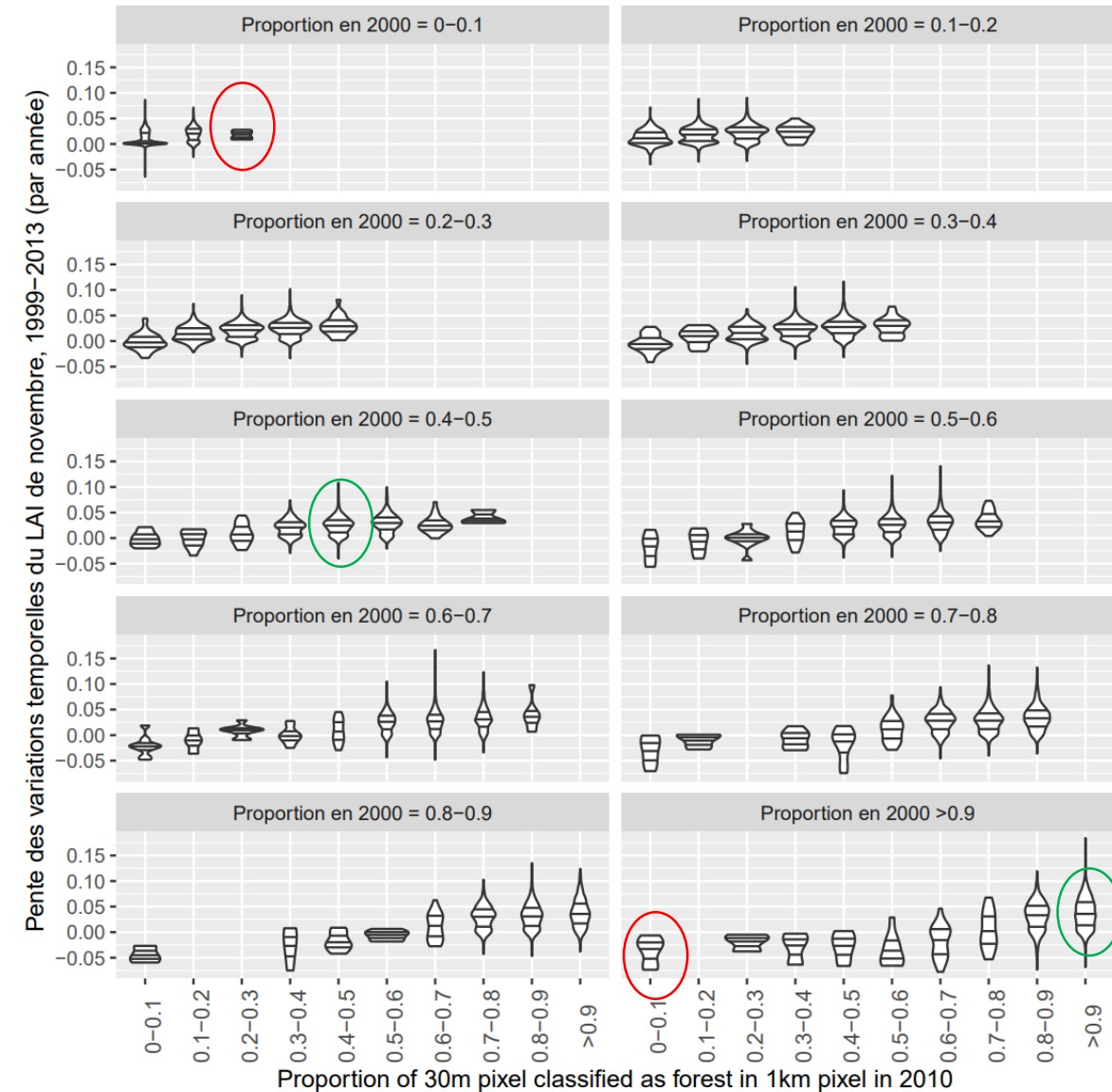
# Evolution temporelle du LAI

Slope of the linear regression of LAI, 1999-2013 (/y)



Large croissance du LAI. La confrontation aux cartes montrant l'évolution de la surface forestière montre que :

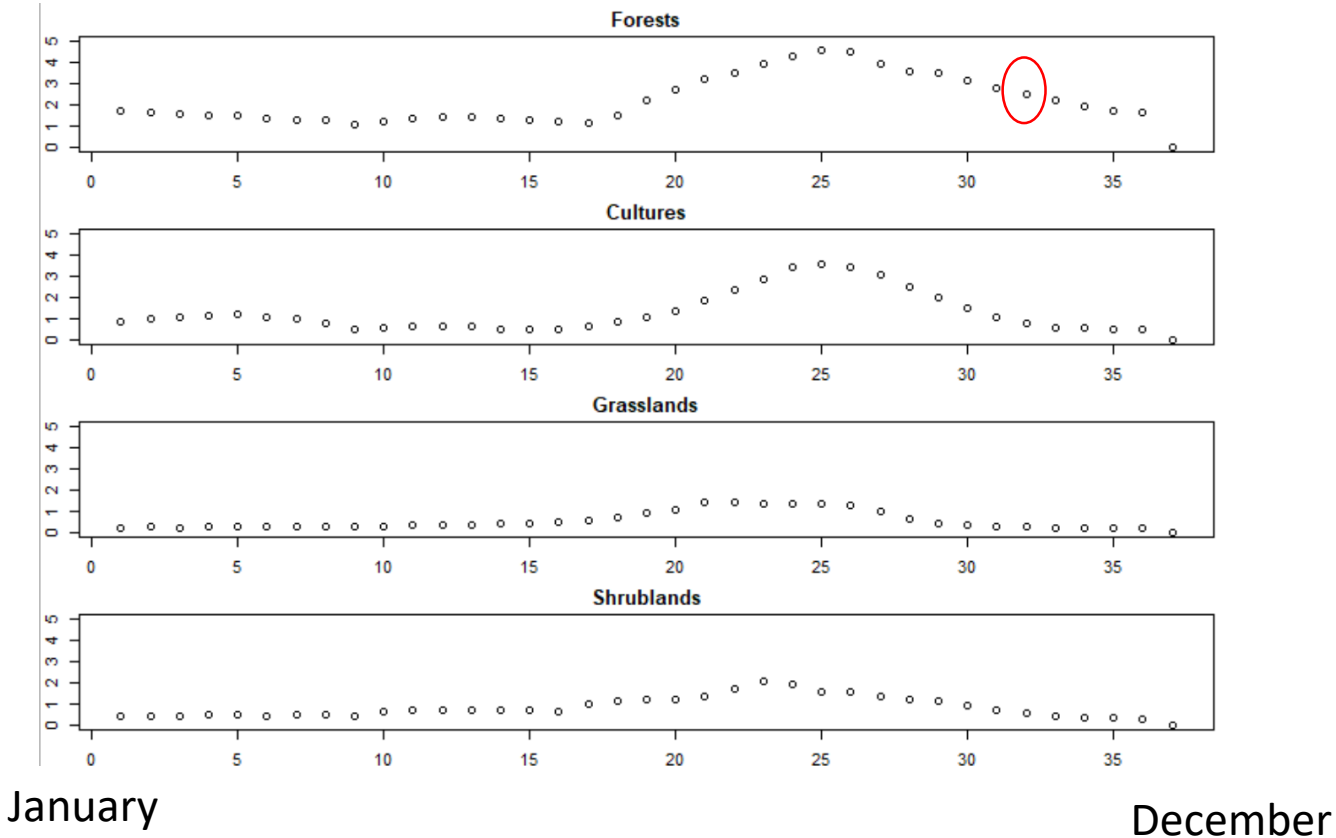
- Une part de l'augmentation est due à du reboisement
- Une part de l'augmentation est due à la densification des forêts



# LAI as a proxy for temporal evolution of forests

November LAI increases from 1999 to 2013

15 year average LAI yearly cycle for pure and stable covers



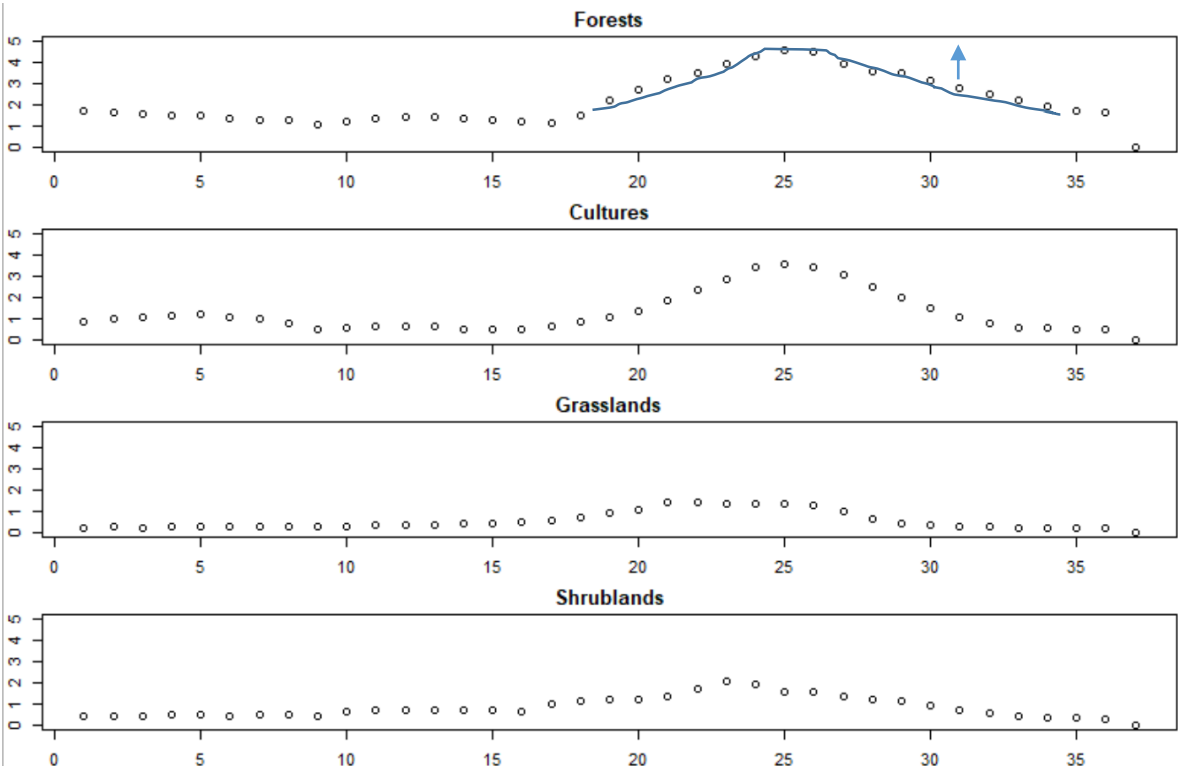
# LAI as a proxy for temporal evolution of forests

November LAI increases from 1999 to 2013

Why :

-densification

15 year average LAI yearly cycle for pure and stable covers



January

December

# LAI as a proxy for temporal evolution of forests

November LAI increases from 1999 to 2013

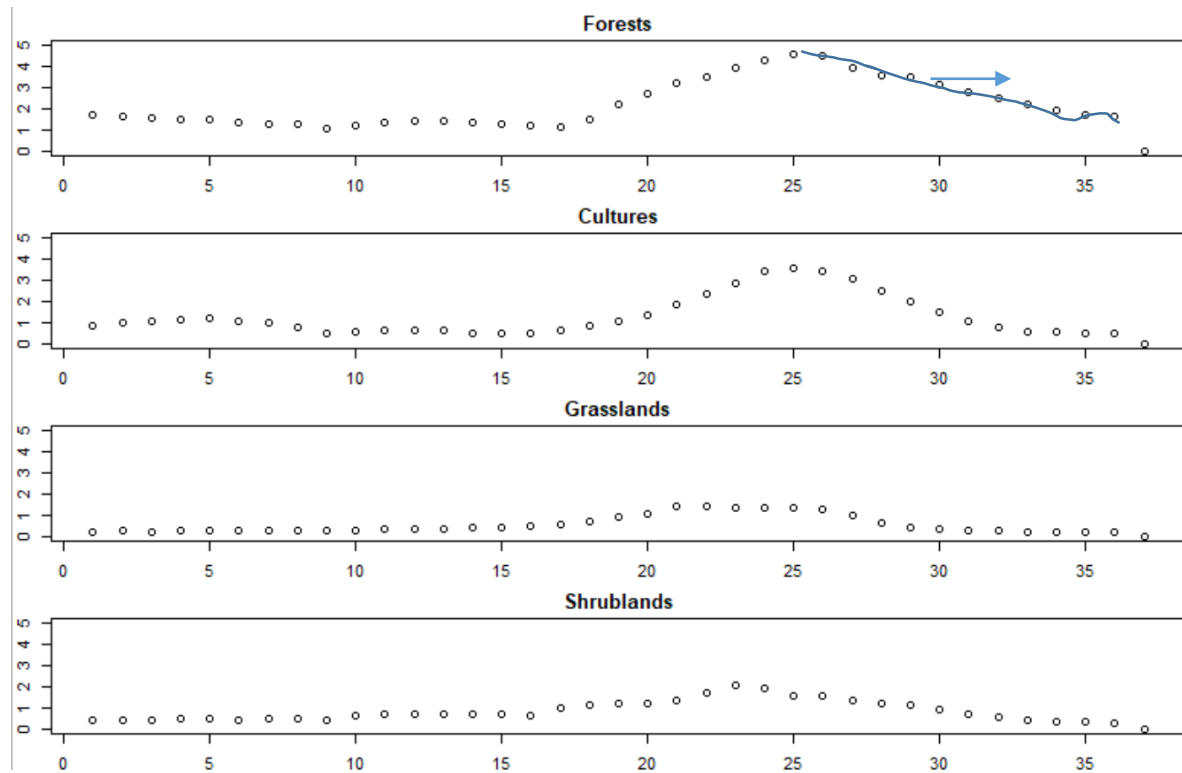
Why :

-densification

-delayed autumn (phenological answer to climate variability)

We cannot exclude that the increase is not related to densification

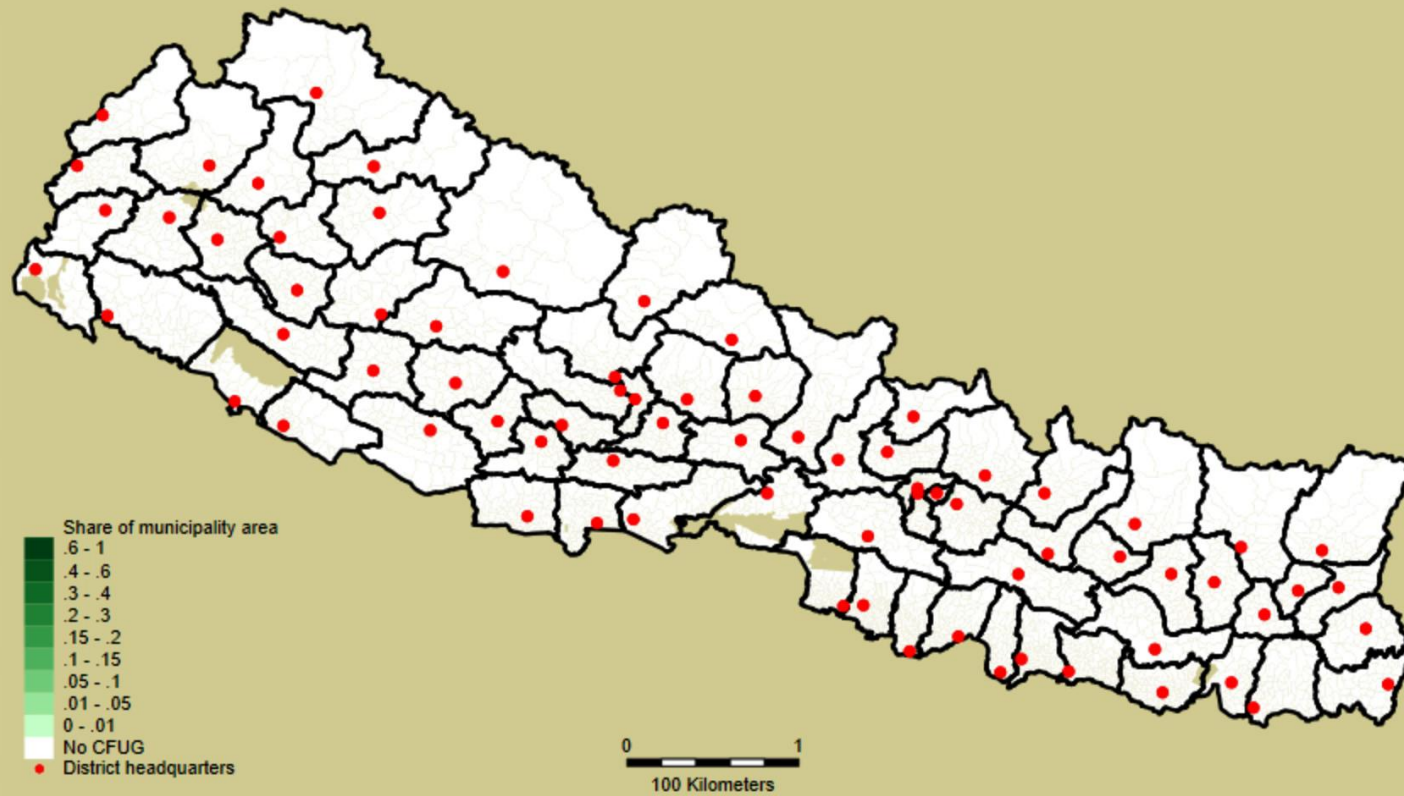
15 year average LAI yearly cycle for pure and stable covers



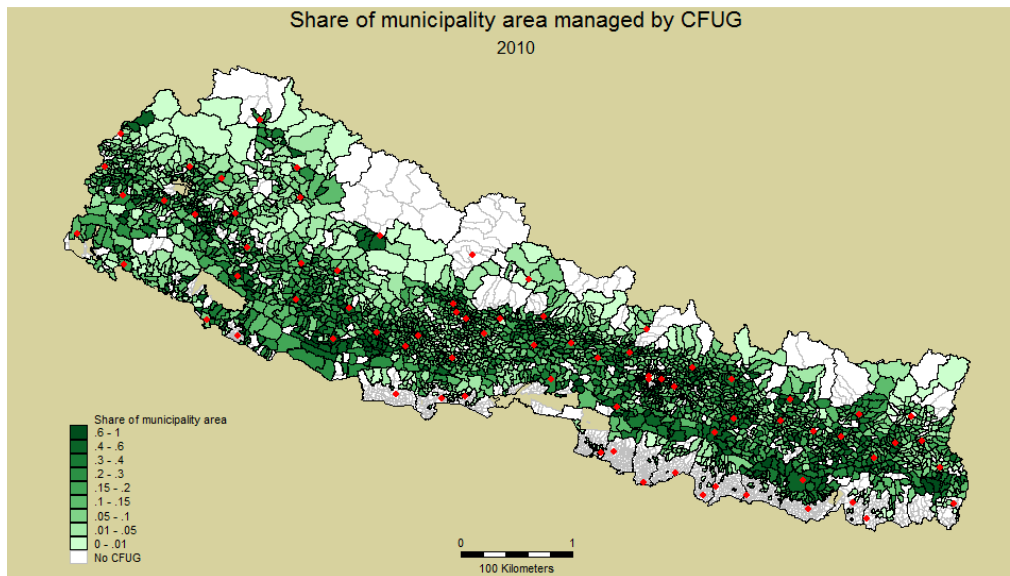
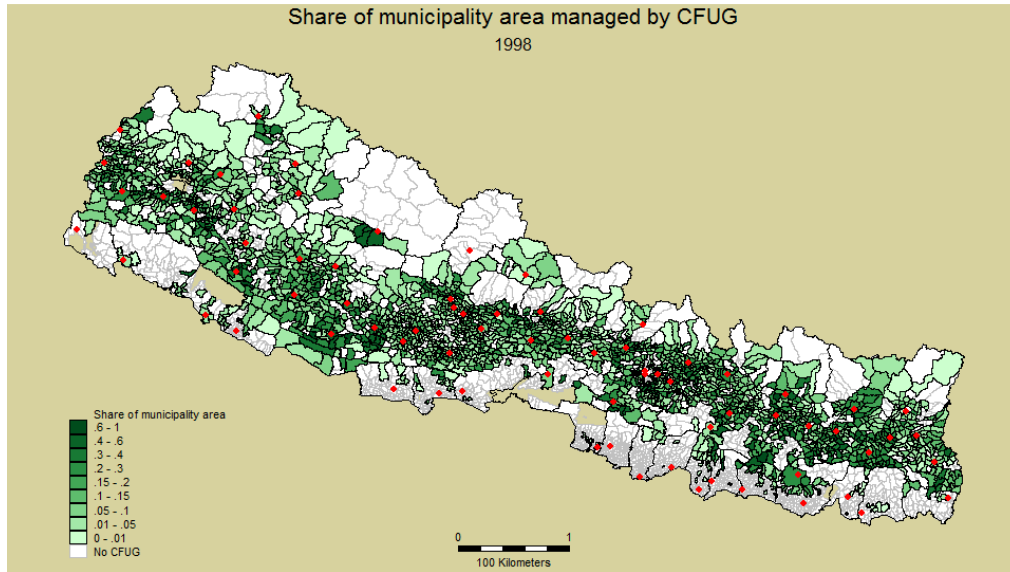
January

December

### Share of municipality area managed by CFUG 1988



Source: Nepal Department of Forest, 2018 - Authors: Baland, Delbart, Libois and Pattanayak (2018)



Statistical analysis of the LAI changes at the VDC level, with regards with the surface fraction managed as CFUG.

# Short- and long- term correlates of CFUG creation on Leaf Area Index (Libois, Baland, Delbart and Pattanayak, 2023)

One may expect reforestation to take time, we therefore estimate the following descriptive relationship

$$LAI_{vt} = \sum_{z=0}^{20} \alpha_z \text{Proportion of VDC area managed by FUG}_{vt-z} + \mathbf{X}_{vt} \Theta + \gamma_v + \delta_{dt} + \varepsilon_{vt} \quad (4)$$

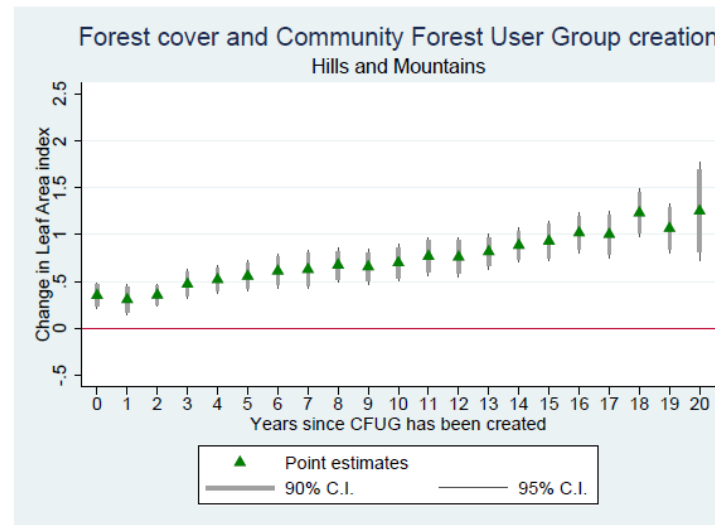
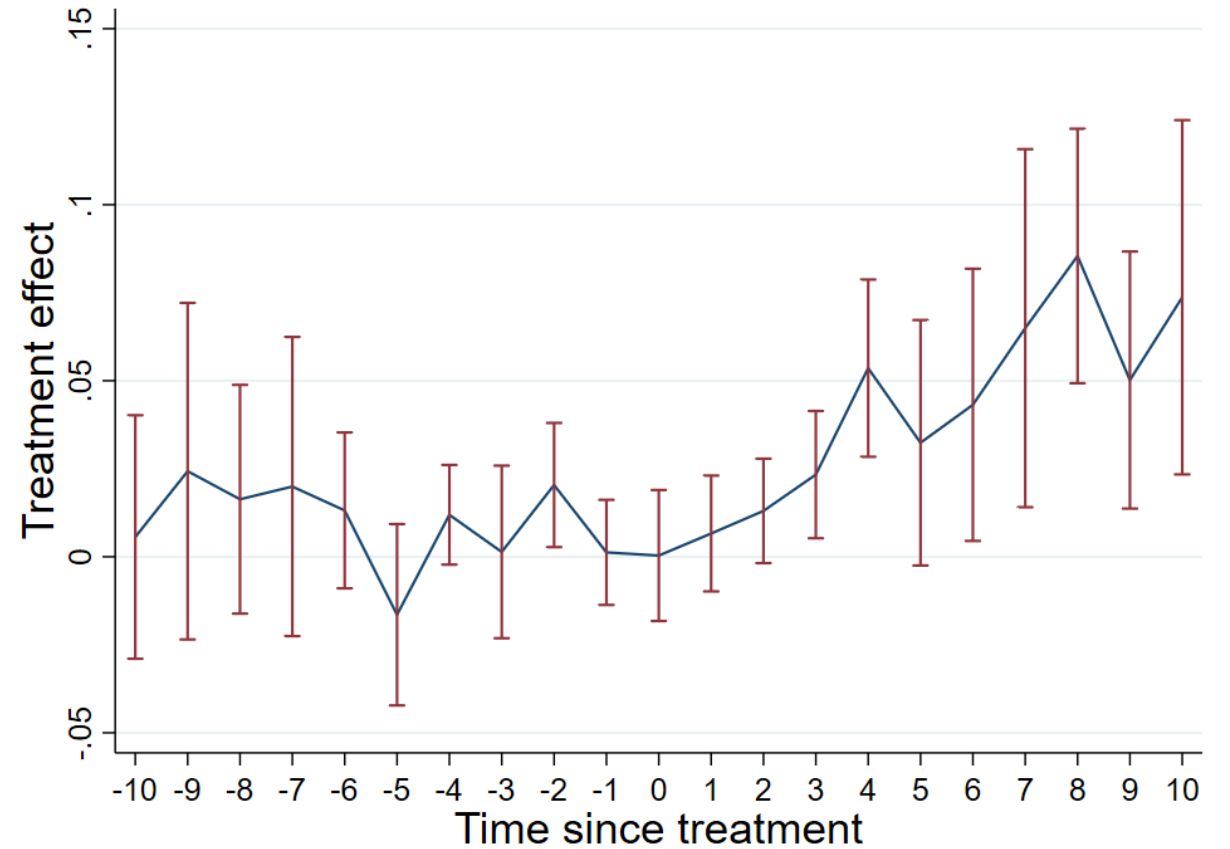
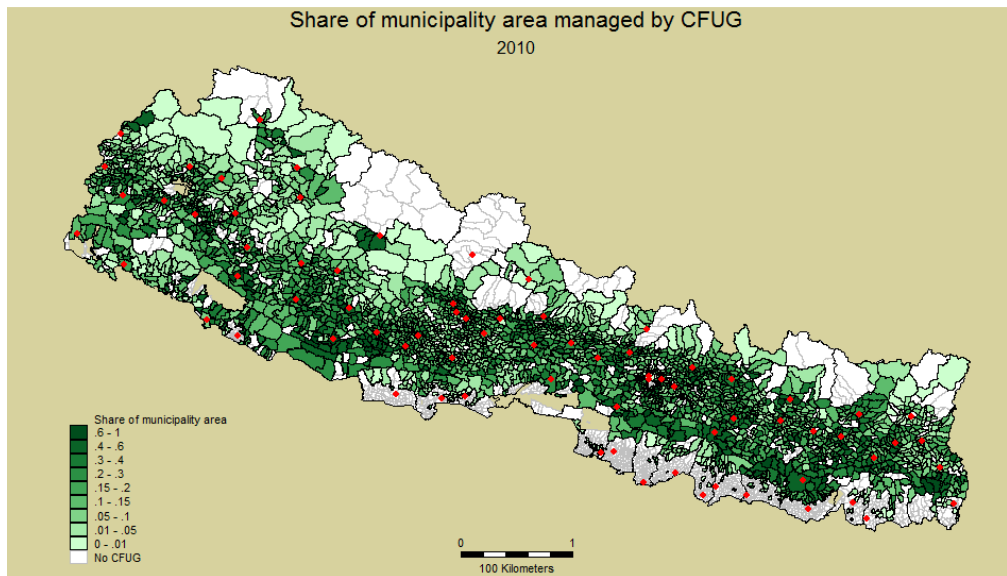
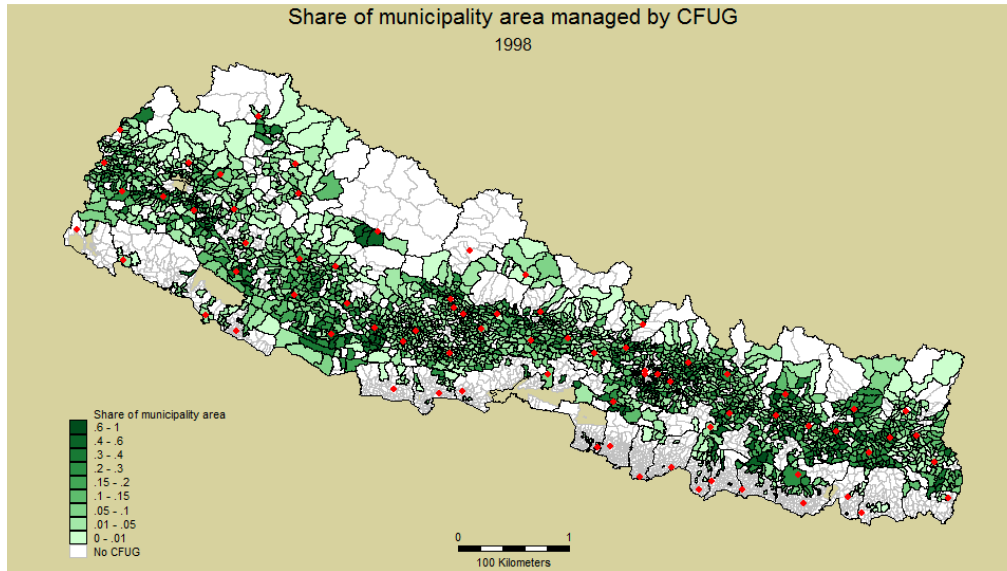


Figure: Forest cover and CFUG creation over time



# Analyse des changements du LAI Vs Part du village gérée en tant que CFUG



On constate que la création de CFUG est suivi d'une croissance du LAI. (Libois et al., soumis)

# Conclusion

**Augmentation du LAI.** Extension spatiale. A partir des données à basse résolution, on voit une augmentation du LAI plus forte en présence de CFUG.

**Perspectives :** utiliser le LAI à 300m (période d'étude jusque 2022) + à 10m (Sentinel2) pour rejoindre l'échelle des CFUG et approfondir la séparation entre densification et extension (landcover).

**Forêts communautaires : modalité de gestion.**

Energie du quotidien. Télédétection / économie. Les CFUGs permettent une régénération forestière, en termes de surface et de densité forestière. Court terme : installation d'unités de biométhanisation + augmentation (faible) des dépenses en substituts énergétiques (gaz, kérosène, charbon de bois).

**Données de terrain + approches interdisciplinaires**