Genesis of millet prices in Senegal: the role of production, markets and their failures

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Earth and Life Institute

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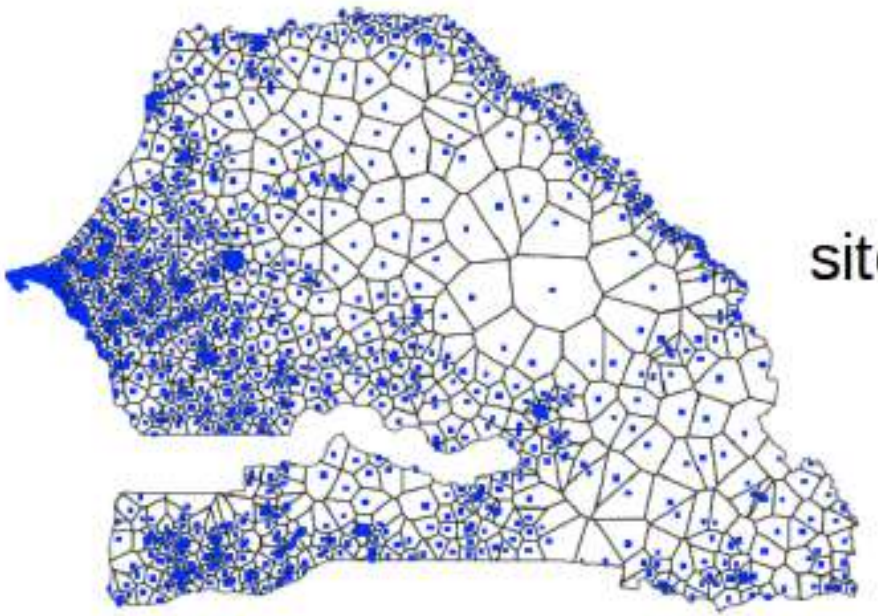
Into the role of a contestant

- Open innovation data challenge on **anonymous call patterns** of Oranges mobile phone users in Senegal.
- Goal: help to **address society development questions** (agriculture, transport, health, energy, national stats) in novel ways by contributing to the socio-economic development and well-being of the Senegalese population.

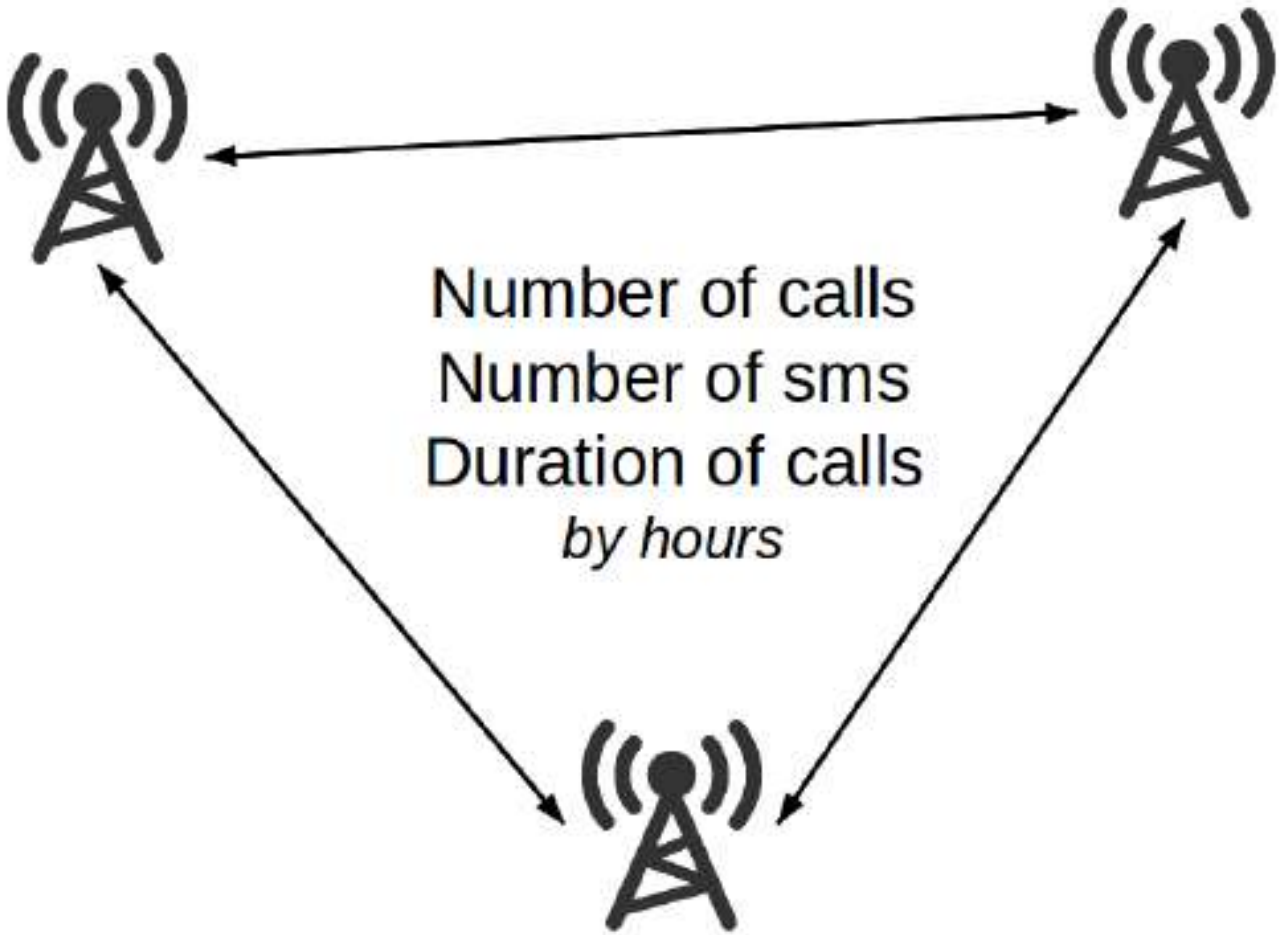
3 datasets, 9 million of Oranges customers

- 3 datasets available based on Call Detail Records (CDR) of phone calls and text exchanges between more than **9 million** of Oranges customers in Senegal between **January 1, 2013 to December 31, 2013**.

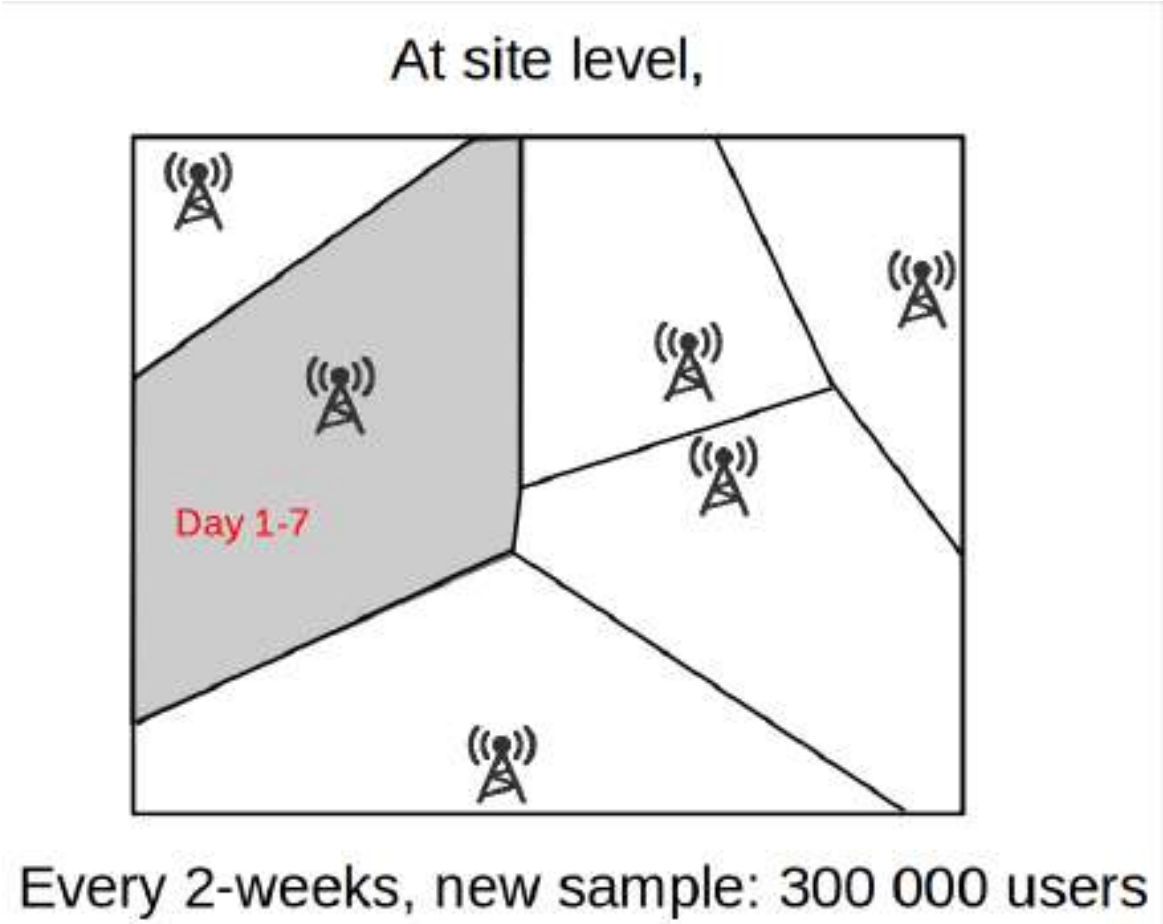


1666
sites / antenna

Dataset 1: Site-to-Site (Antenna-to-Antenna) traffic



Dataset 2: Fine-grained mobility



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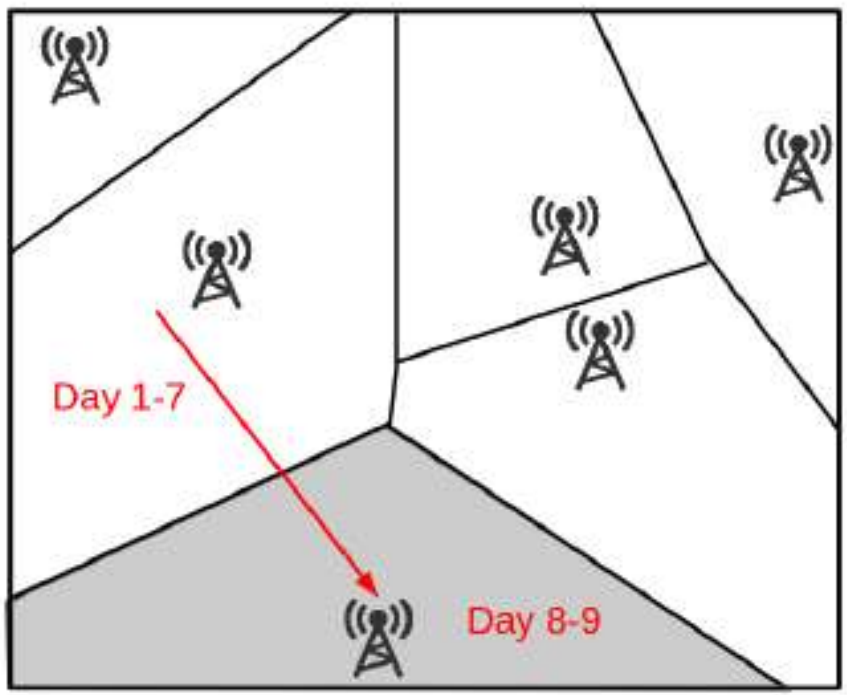

Every 2-weeks, new sample: 300 000 users

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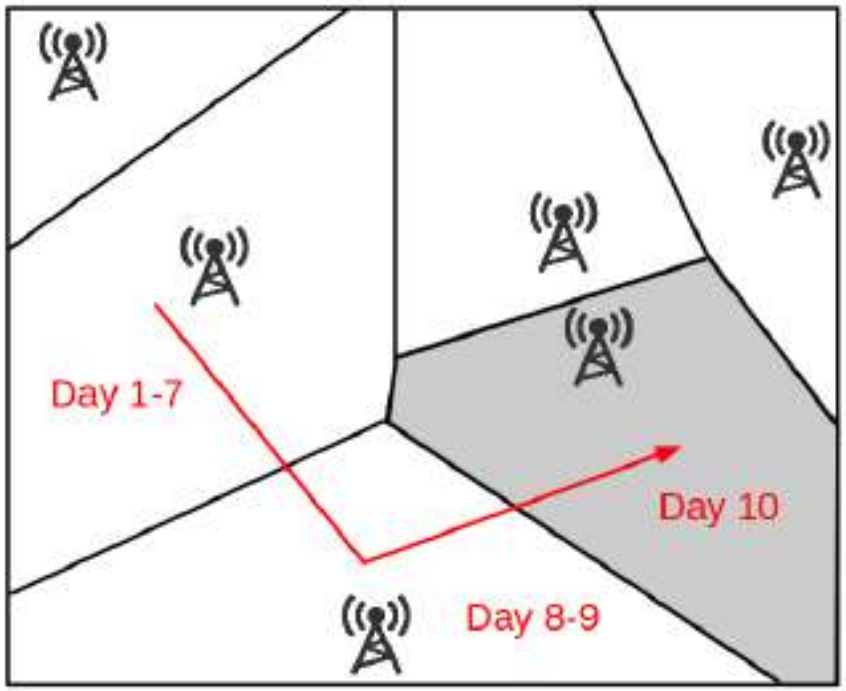

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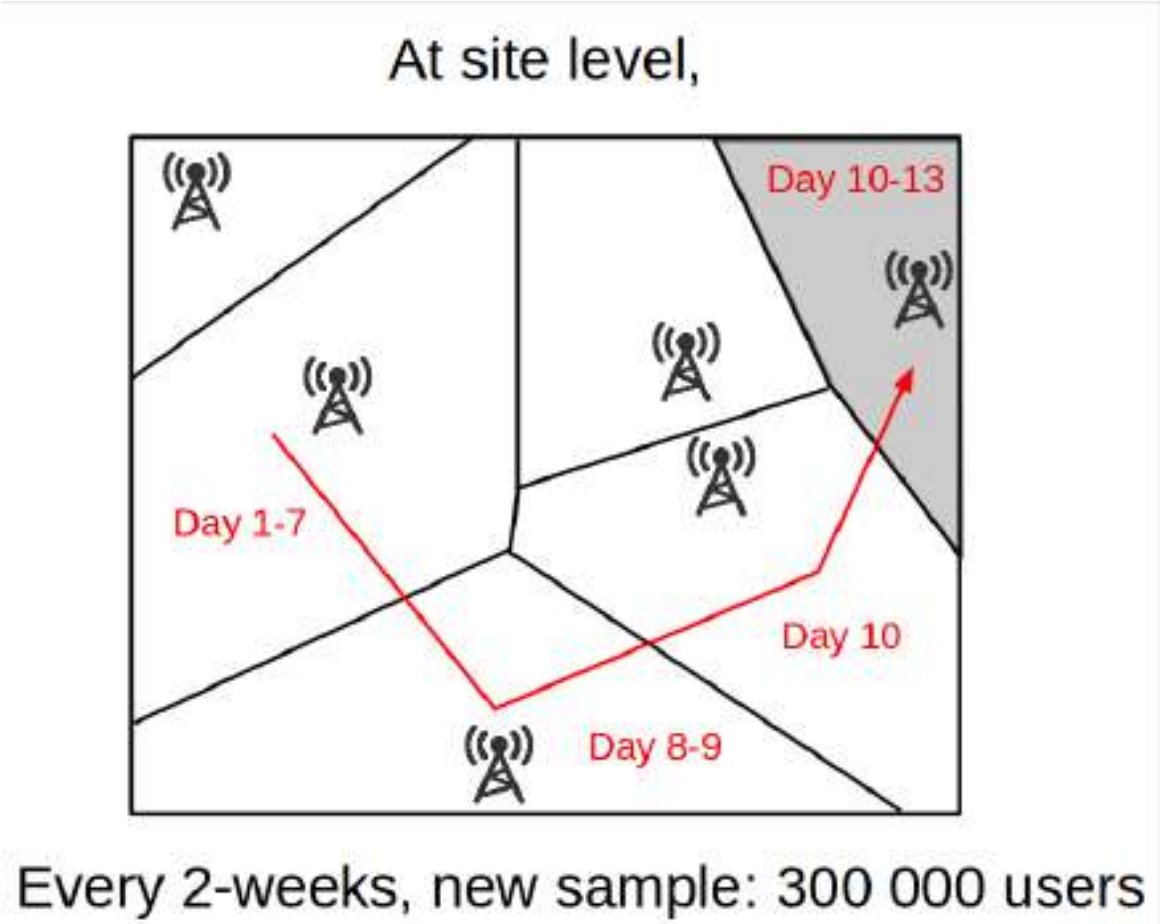

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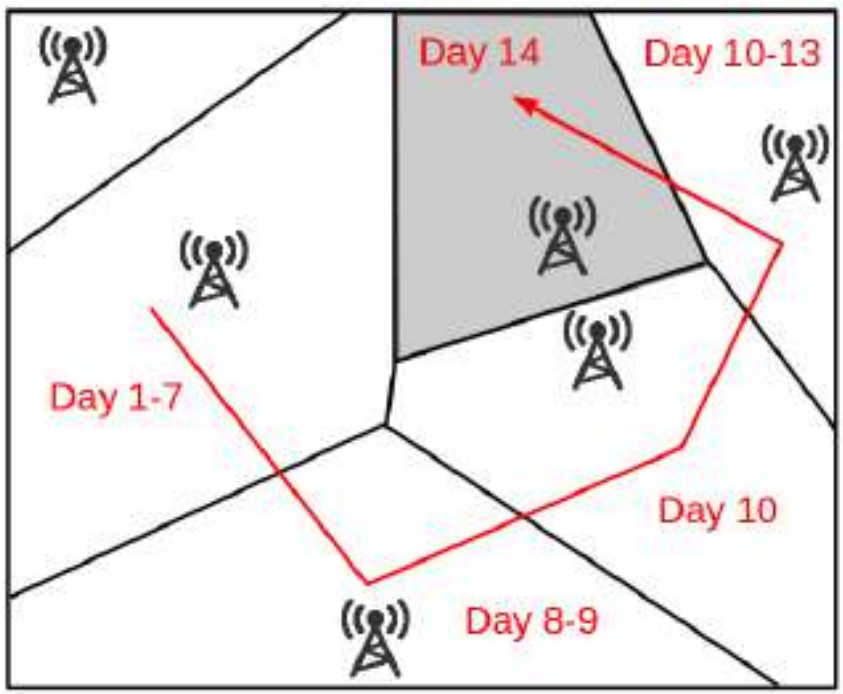

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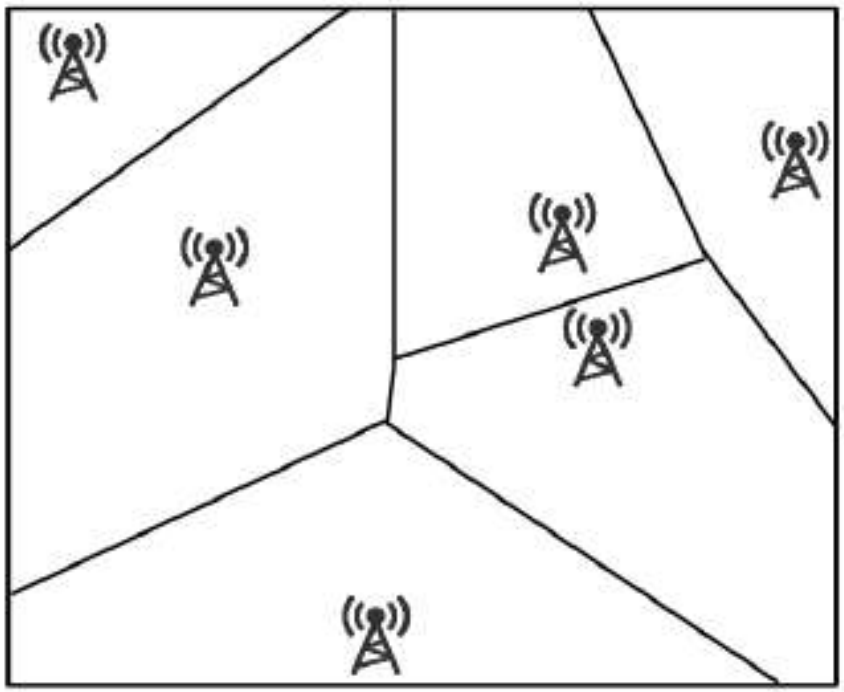
Dataset 3: Coarse-grained mobility

At arrondissement level,



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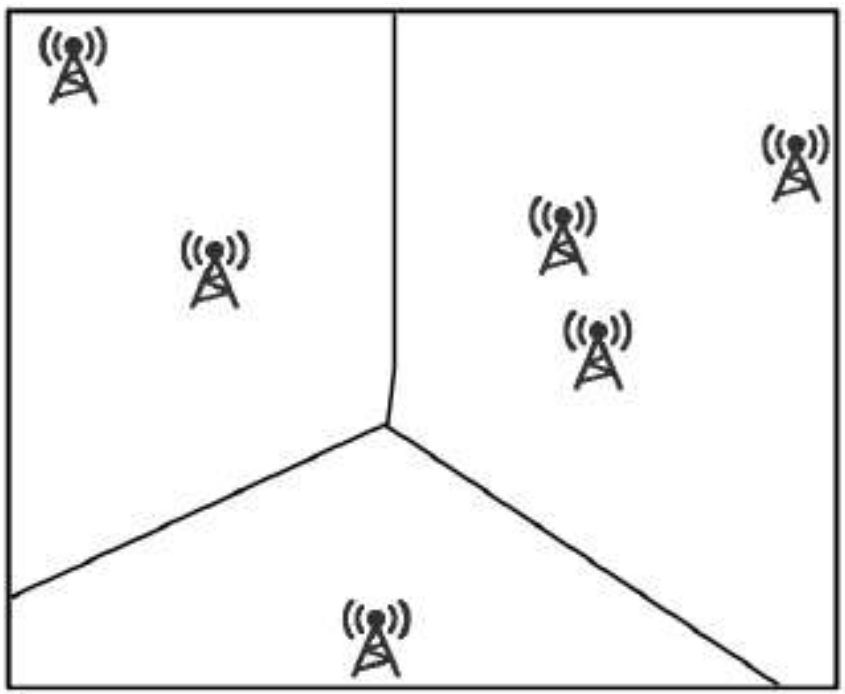

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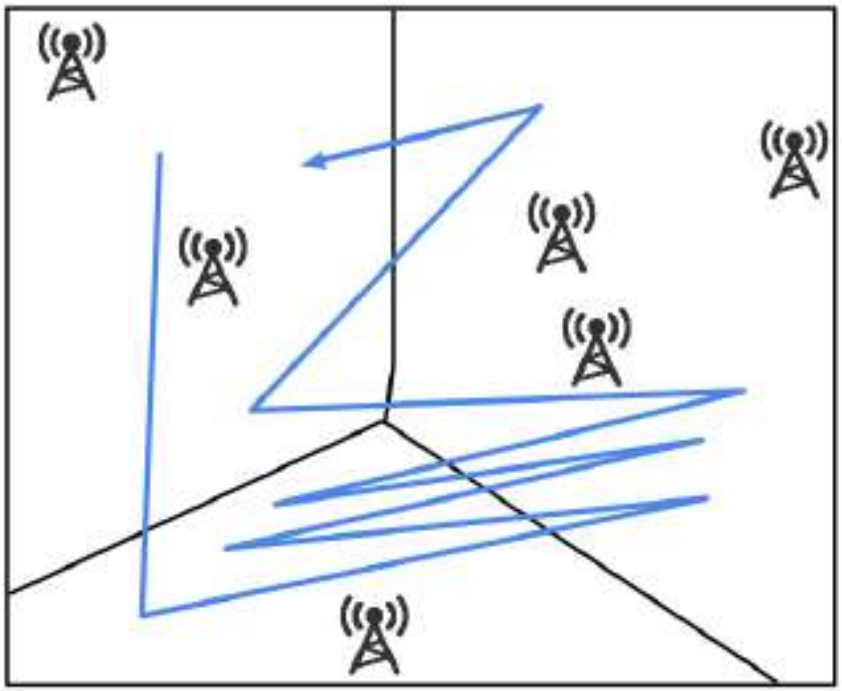

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Focus on 2 components of Food Security

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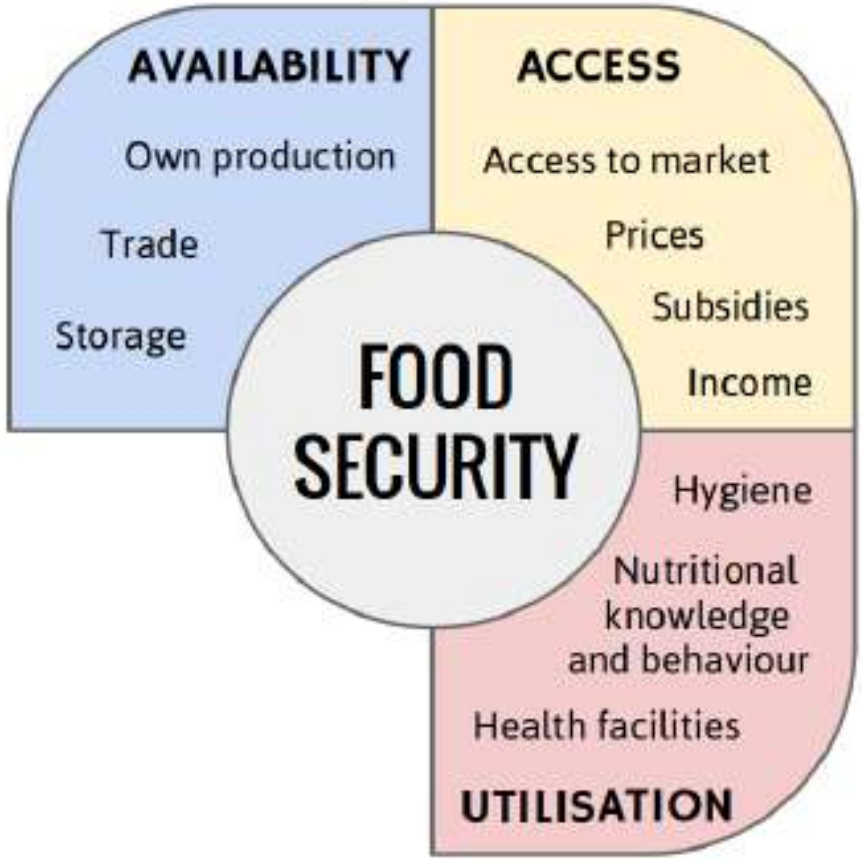

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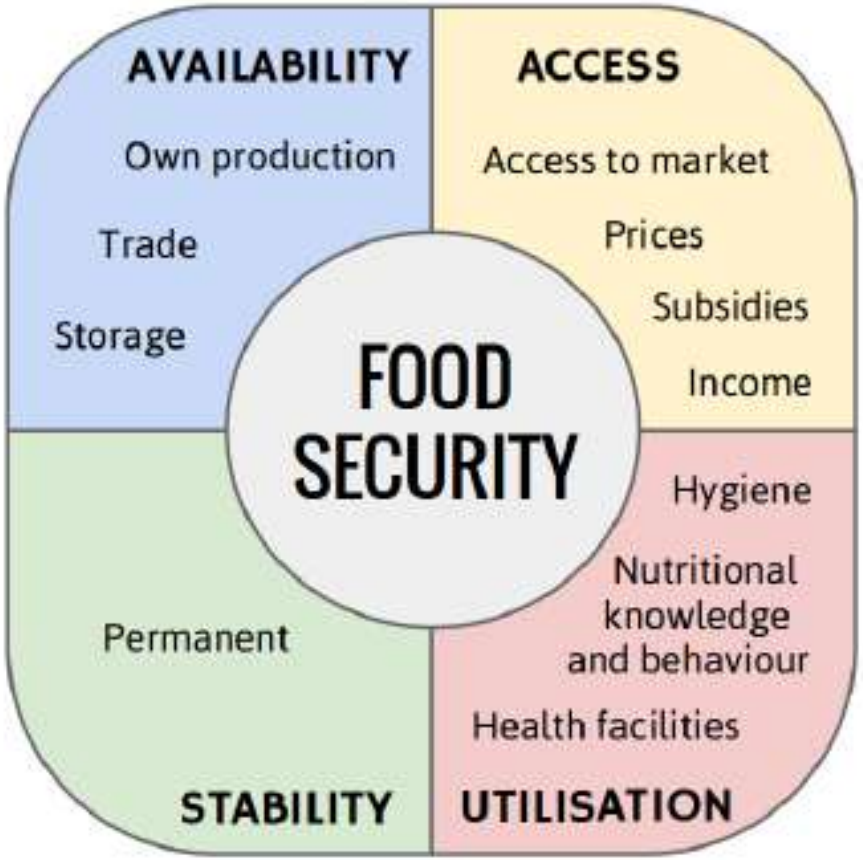

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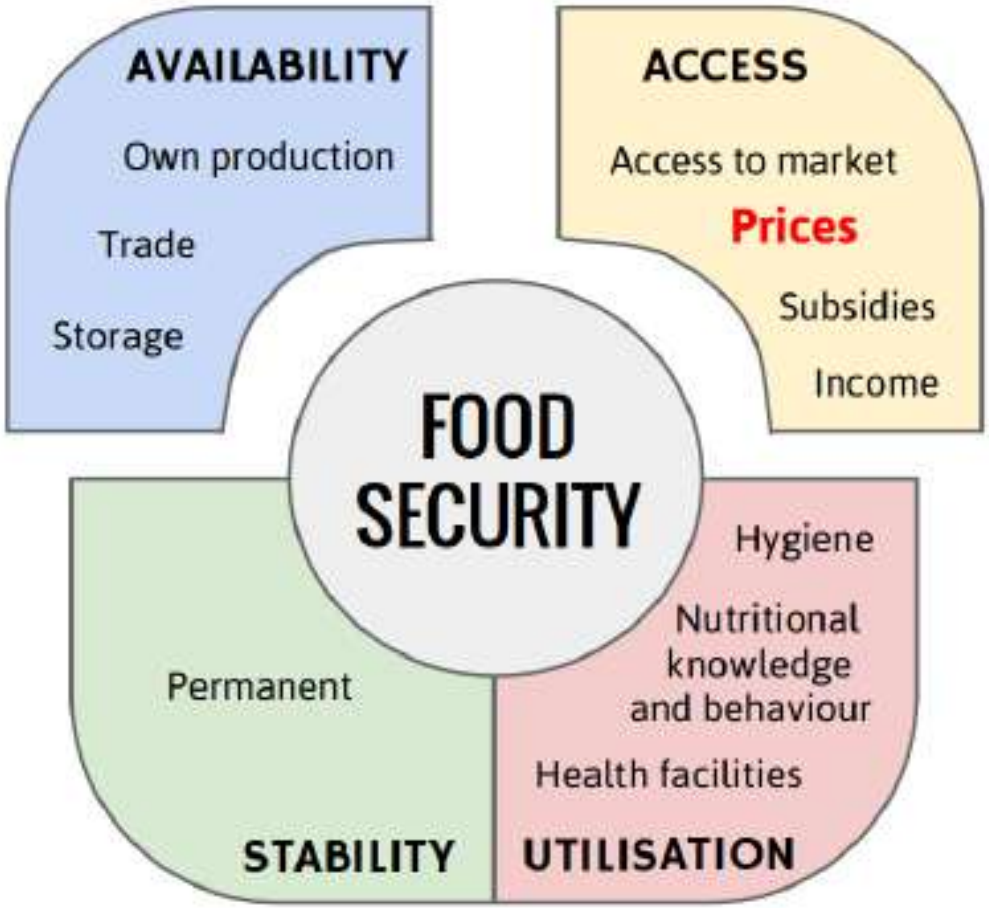


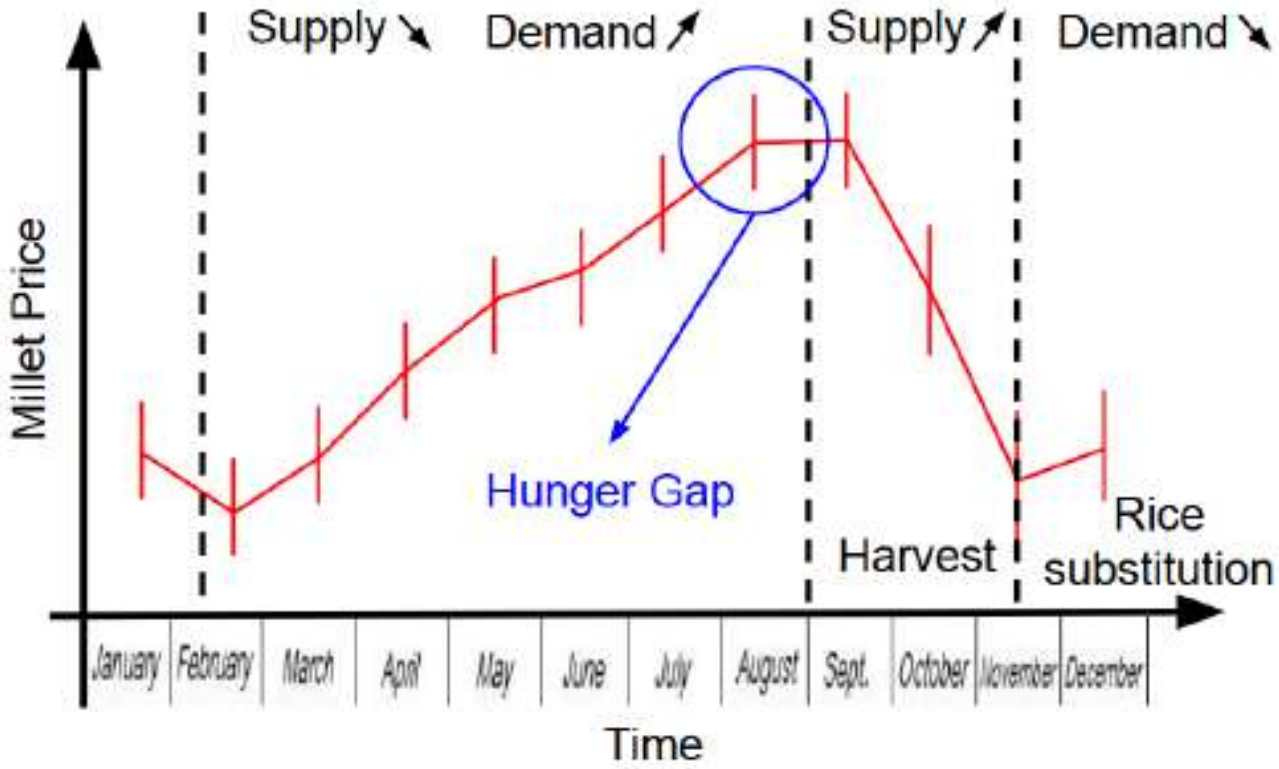
Understand the market functioning by studying the formation of millet prices

- **Research question**: how can we explain the differences of millet prices observed in Senegalese markets ? Are they coming from market failures ?
- Working on **millet**: most widely available grain and the most frequently purchased when famers' own production is exhausted



Typical evolution of millet prices in Senegal

- Strong **intra-annual variation**
- Harvest time: from **September** to **November**
- Lack of **storage facilities** (not available or costly)



Genesis of a price: the case of an isolated market

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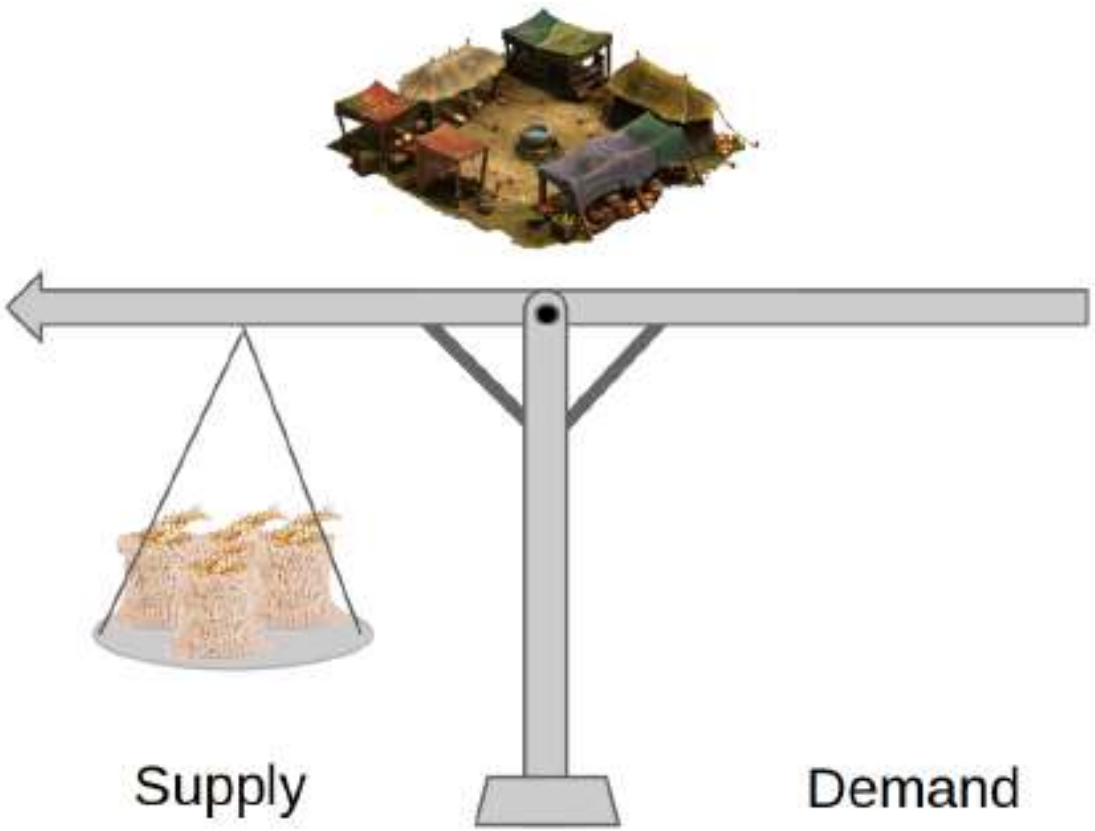

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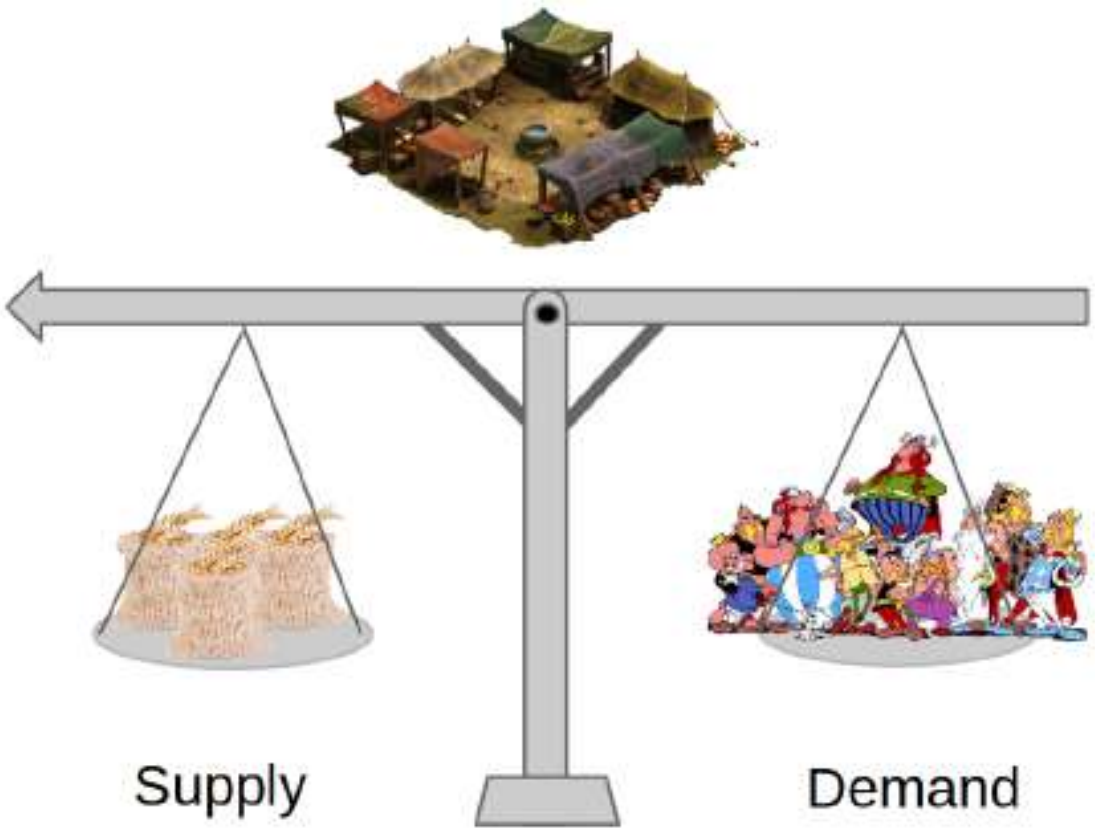

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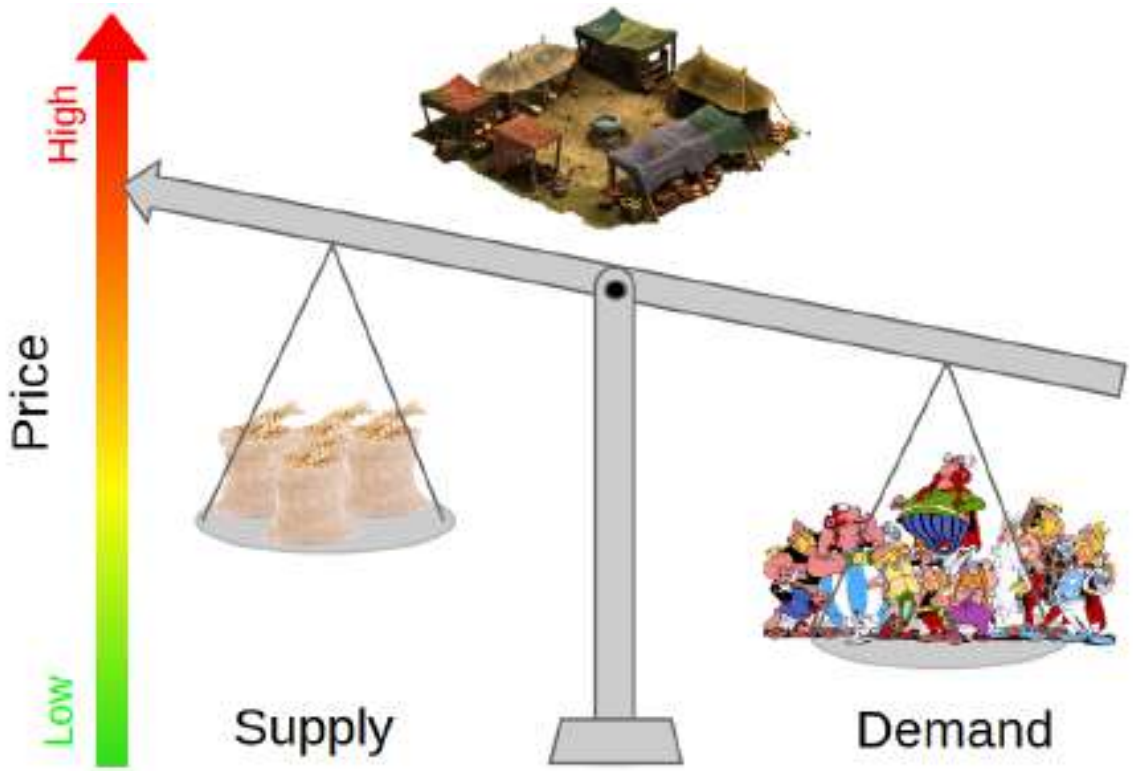

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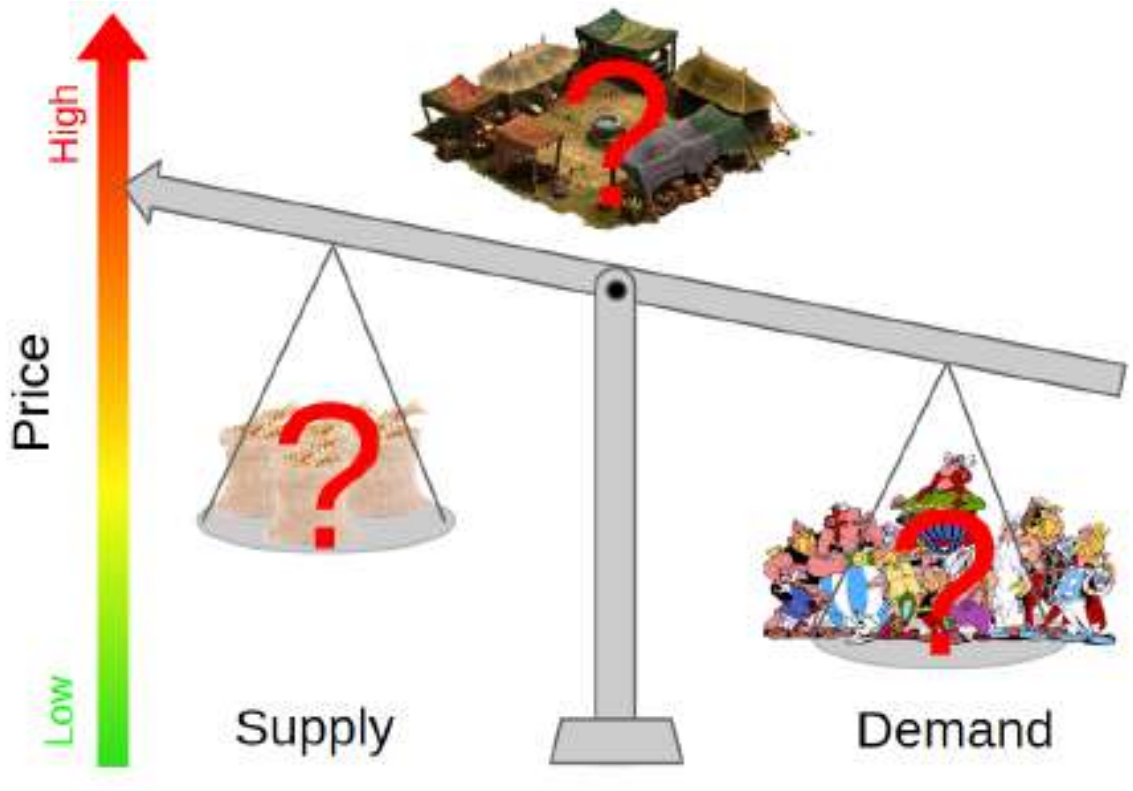


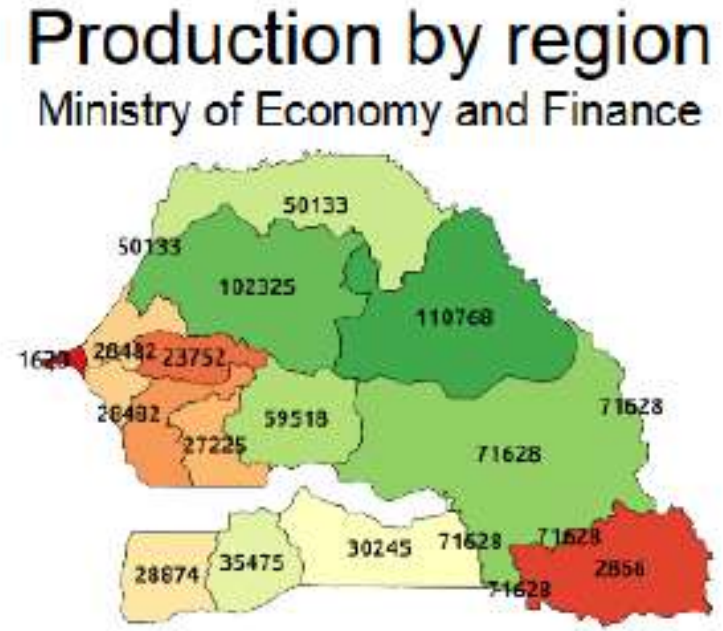
Retail Millet prices of 42 markets are studied (UN WFP)

- Catchment area of each market are computed thanks to the road network

42 markets

Minimum travelling times (road from the Global Insight dataset)

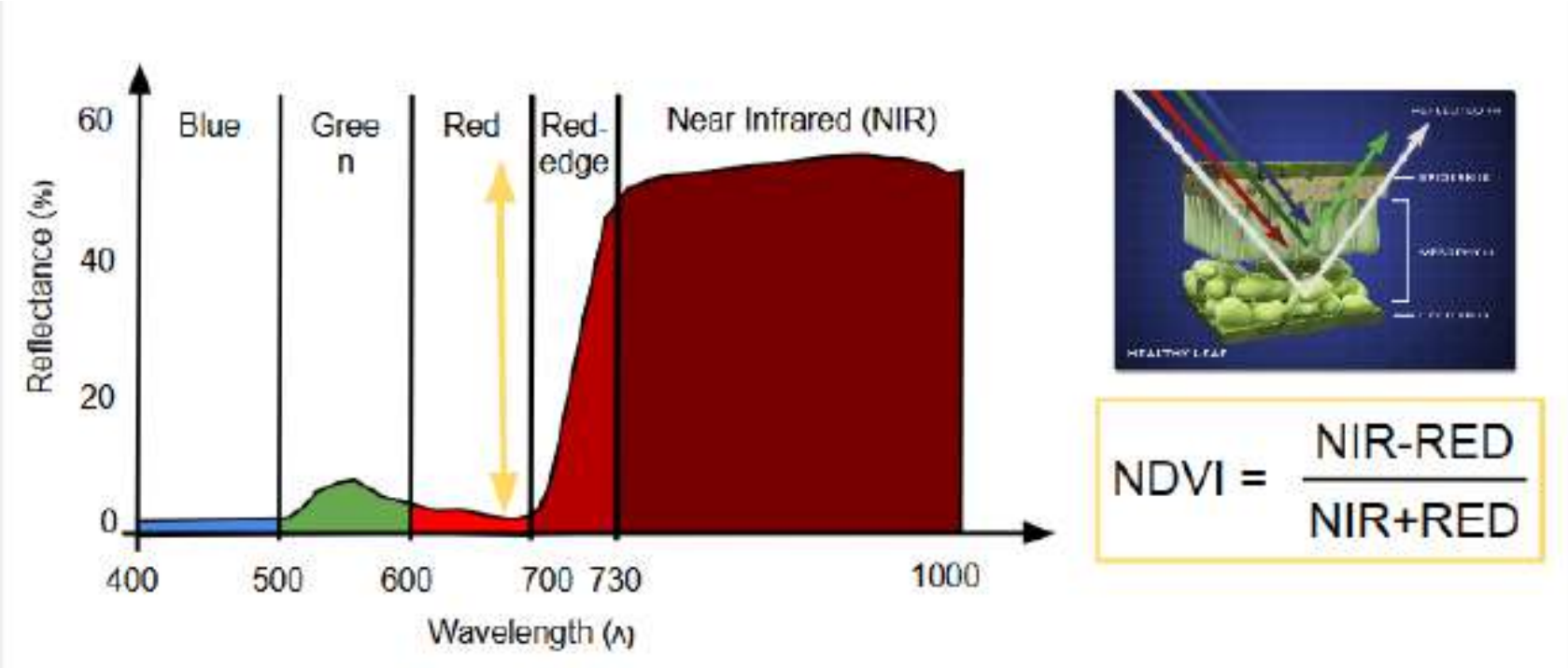
Production is estimated using national statistics and vegetation index



Need production by market

Production is estimated using national statistics and vegetation index

- The Normalized Difference Vegetation Index (NDVI) is widely used to monitor green vegetation based on its spectral signature



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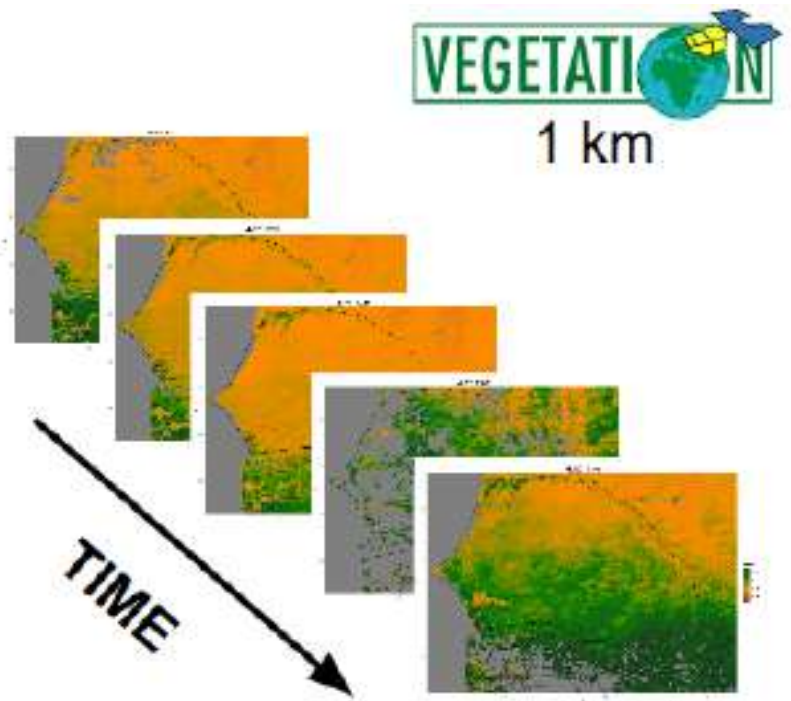
- The NDVI is computed on SPOT-V (1 km) time series



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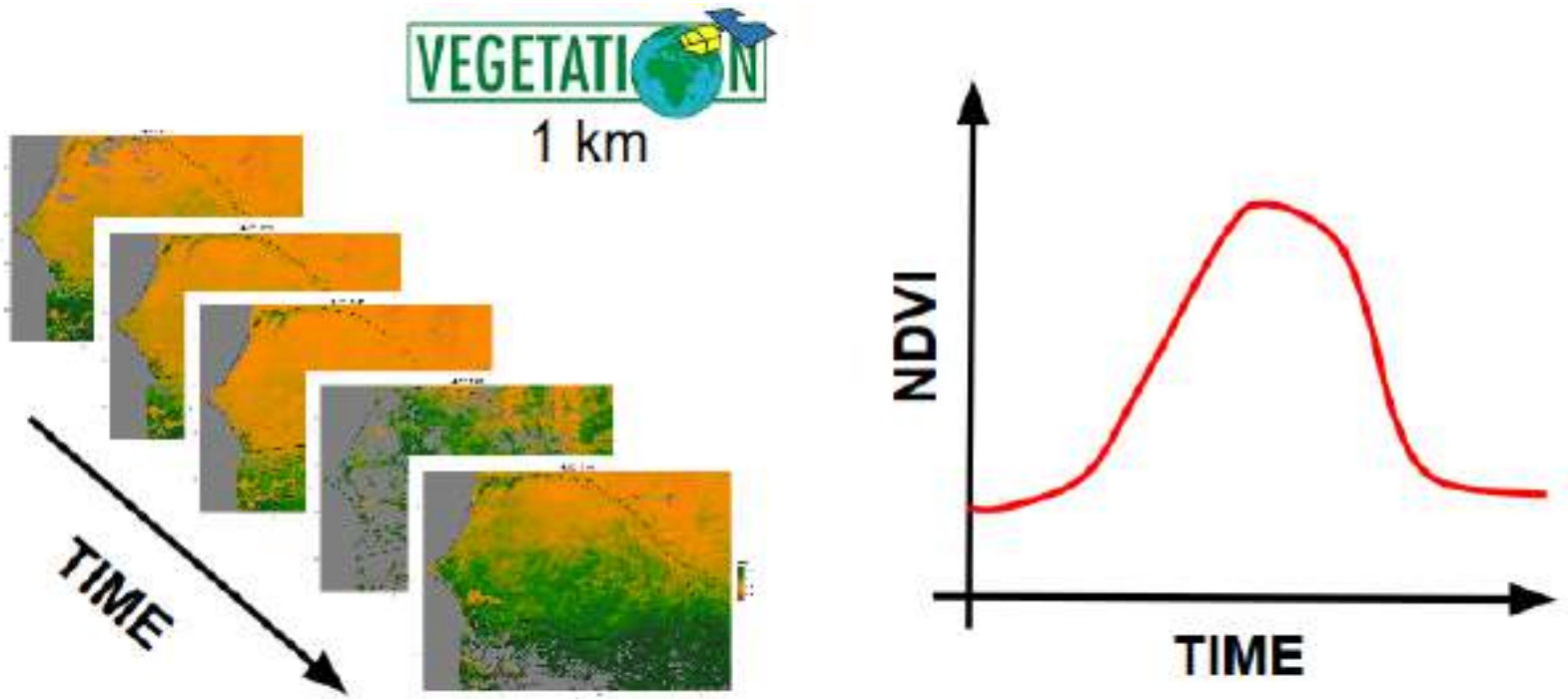

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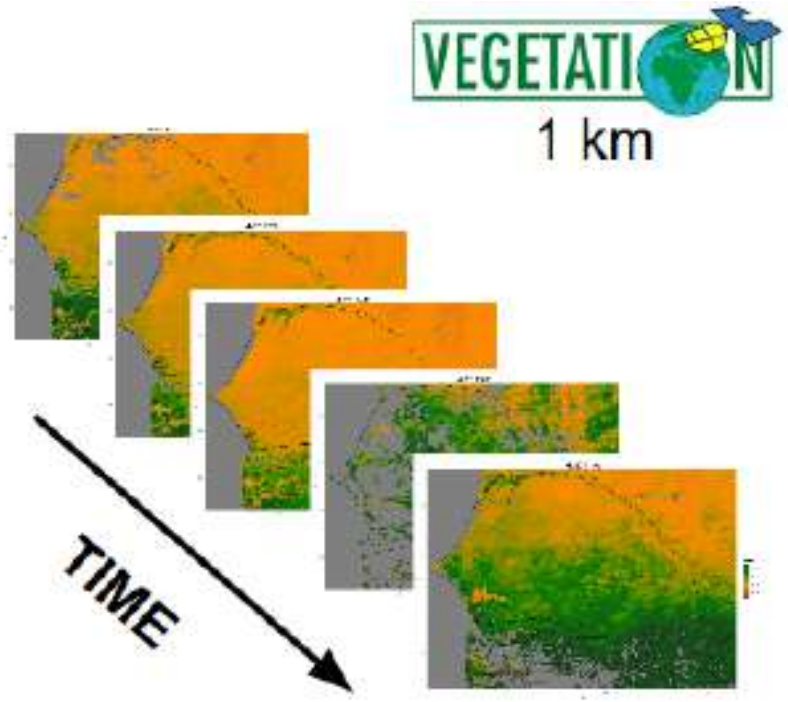
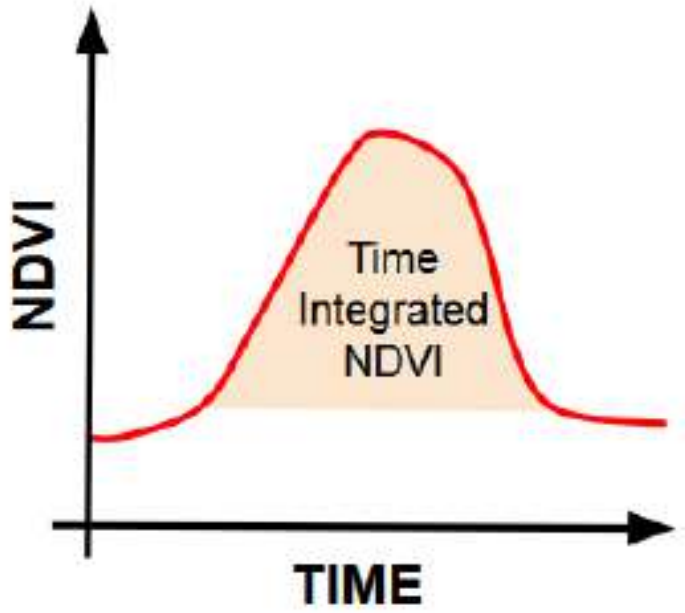
- The Time Integrated NDVI (TNDVI) is used as a proxy of the level of crop production in one pixel.





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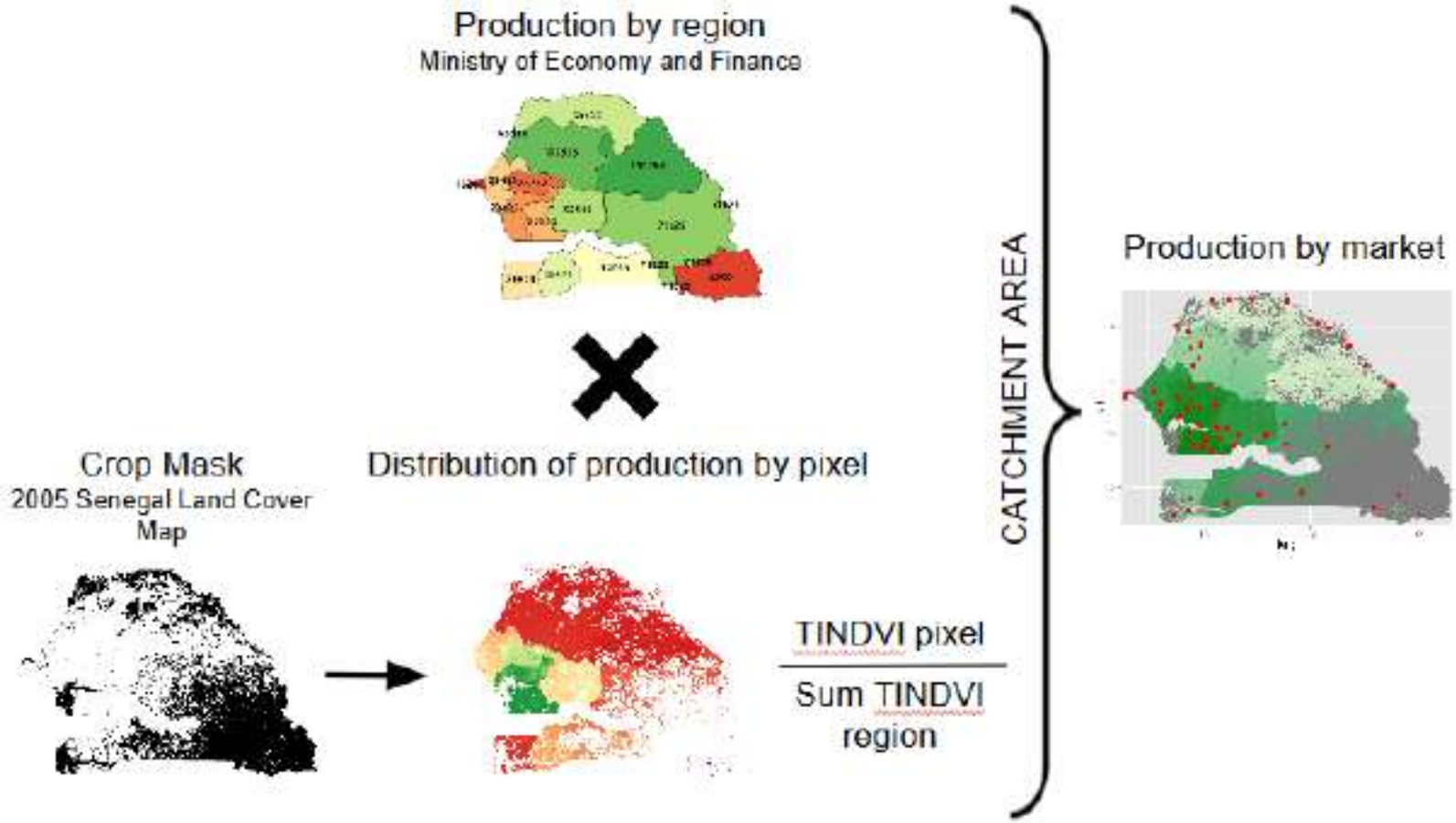
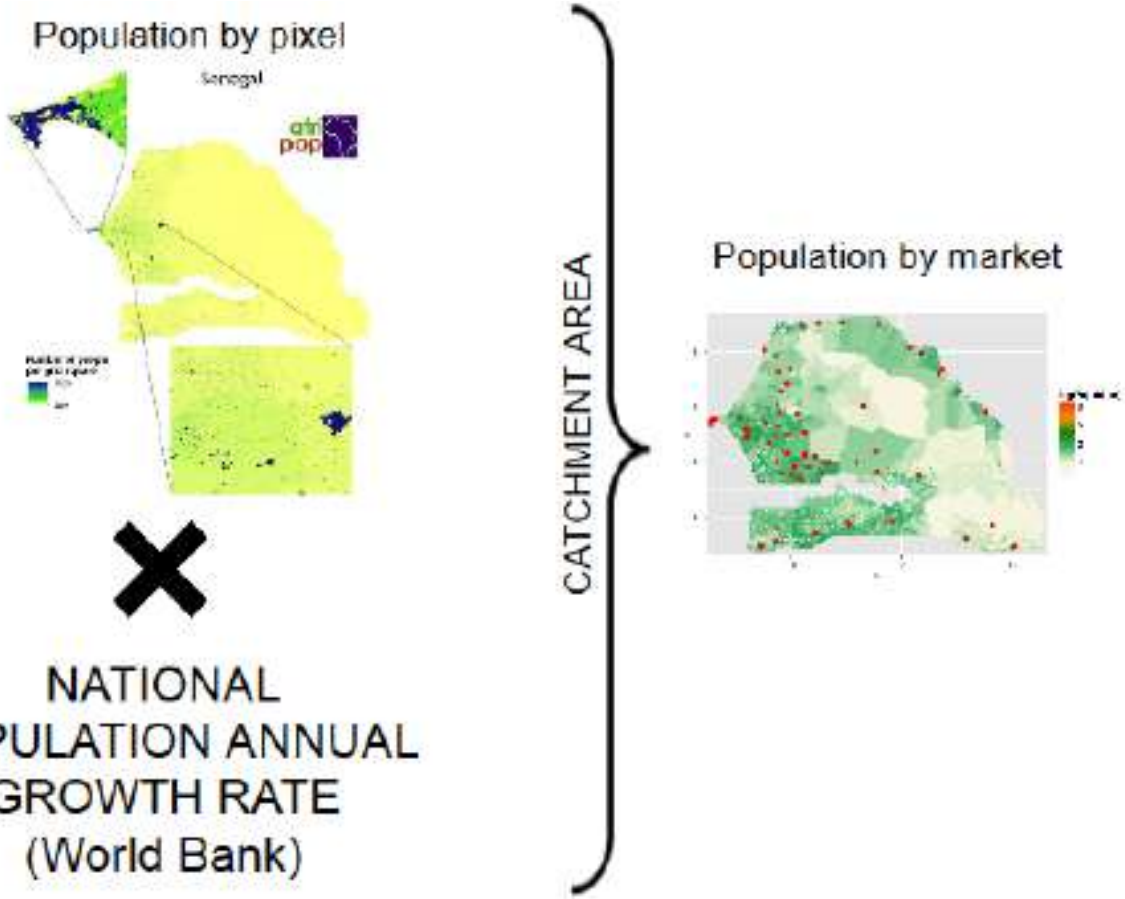


Population is estimated using AfriPop dataset and national growth rate



Pseudo-Price can be computed as the ratio of population on production of each market

- Pseudo-Prices are correlated with real Prices.
- **Results are poor**: $R^2 = 0.26$ for April and $R^2 = 0.23$ for August. Allow us to **reject the perfect markets segregation** in Senegal

$$P_i \propto PsPr_i = \frac{Pop_i}{Prod_i + 1}$$

where $PsPr_i$, Pop_i, $Prod_i$ are the pseudo-price, the population and the production for the catchment area cover by the market i.

Genesis of a price: the case of interconnected markets

2 $

5 $

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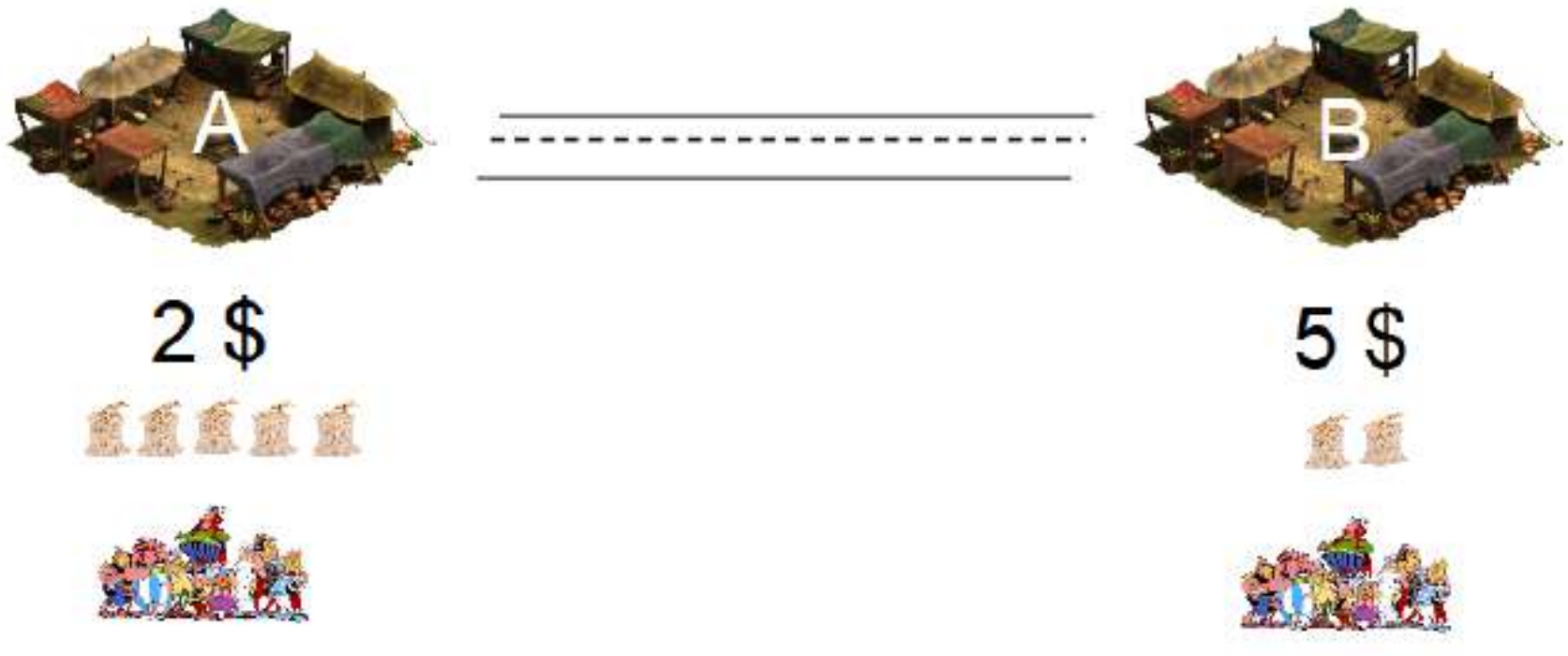

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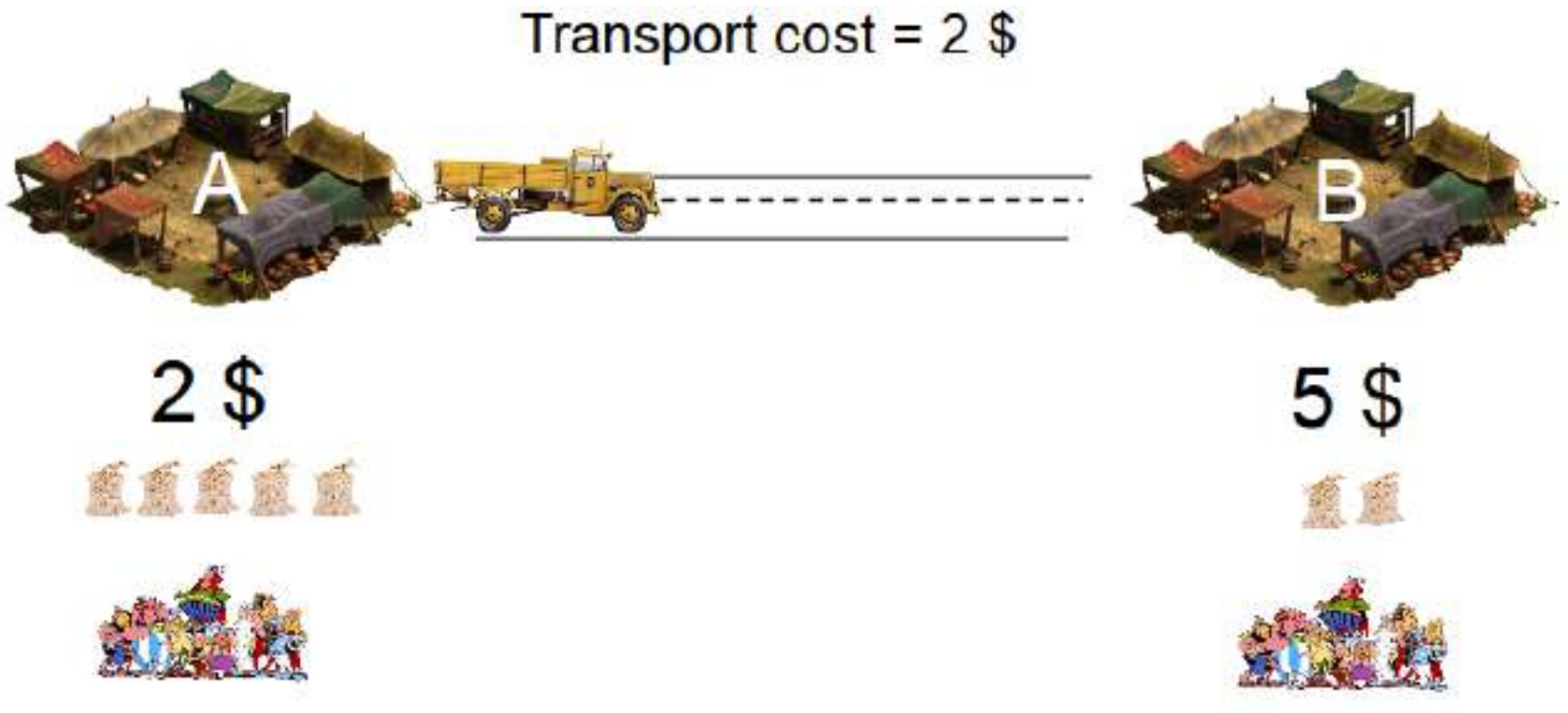

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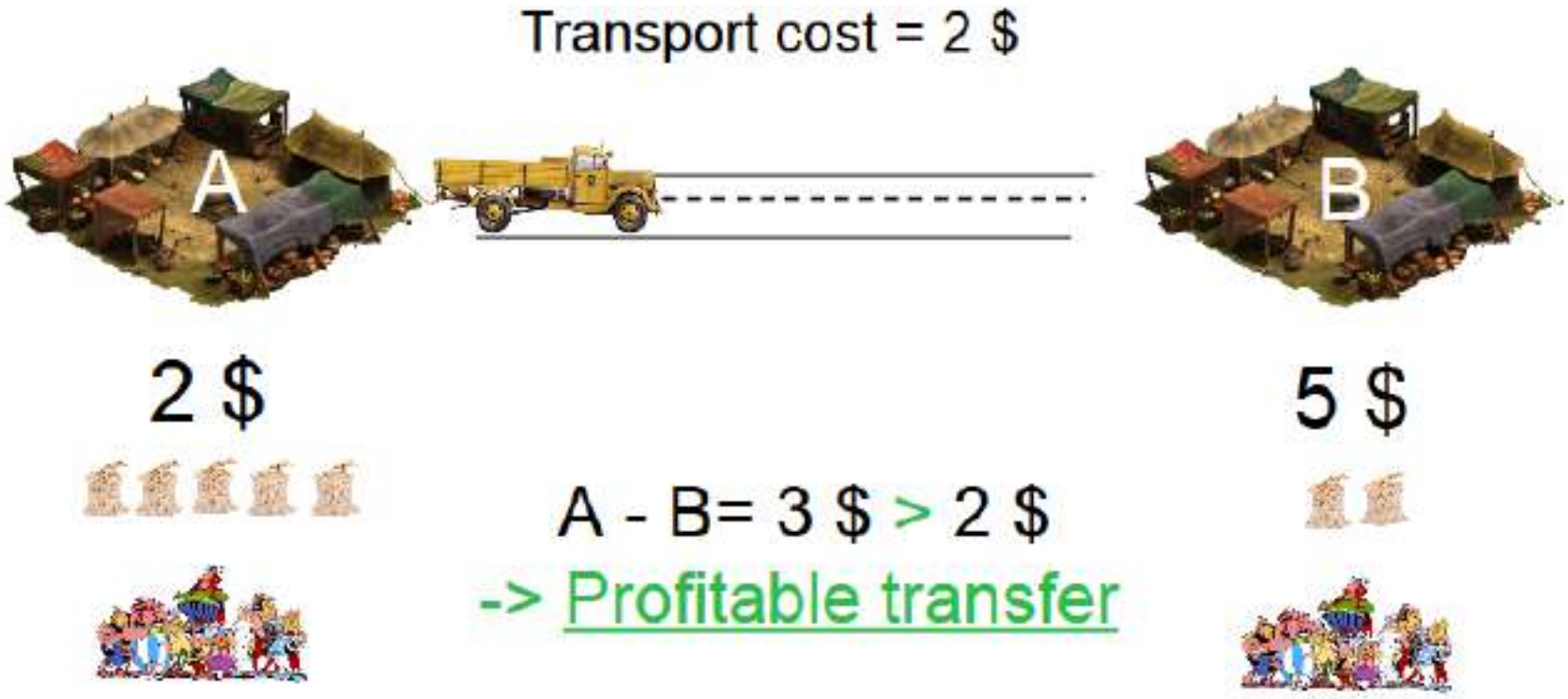

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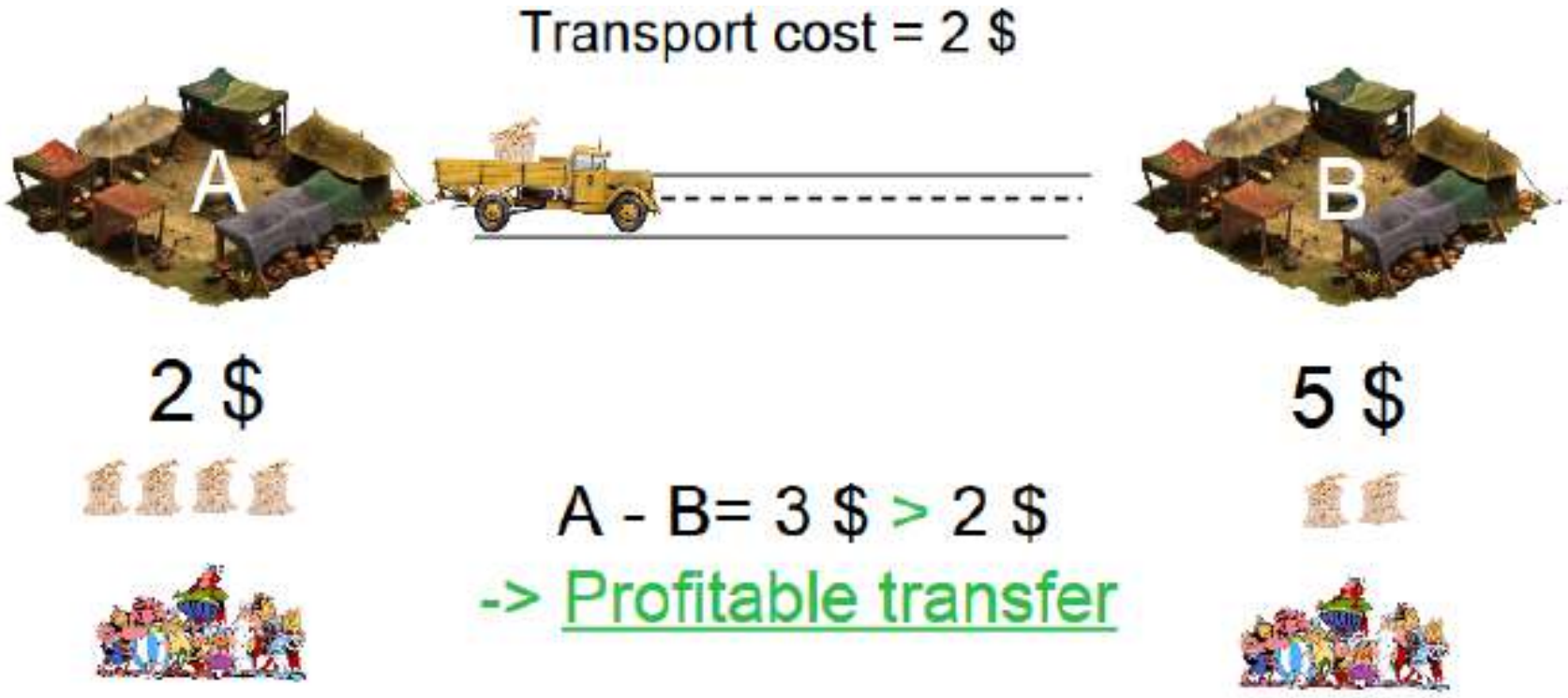

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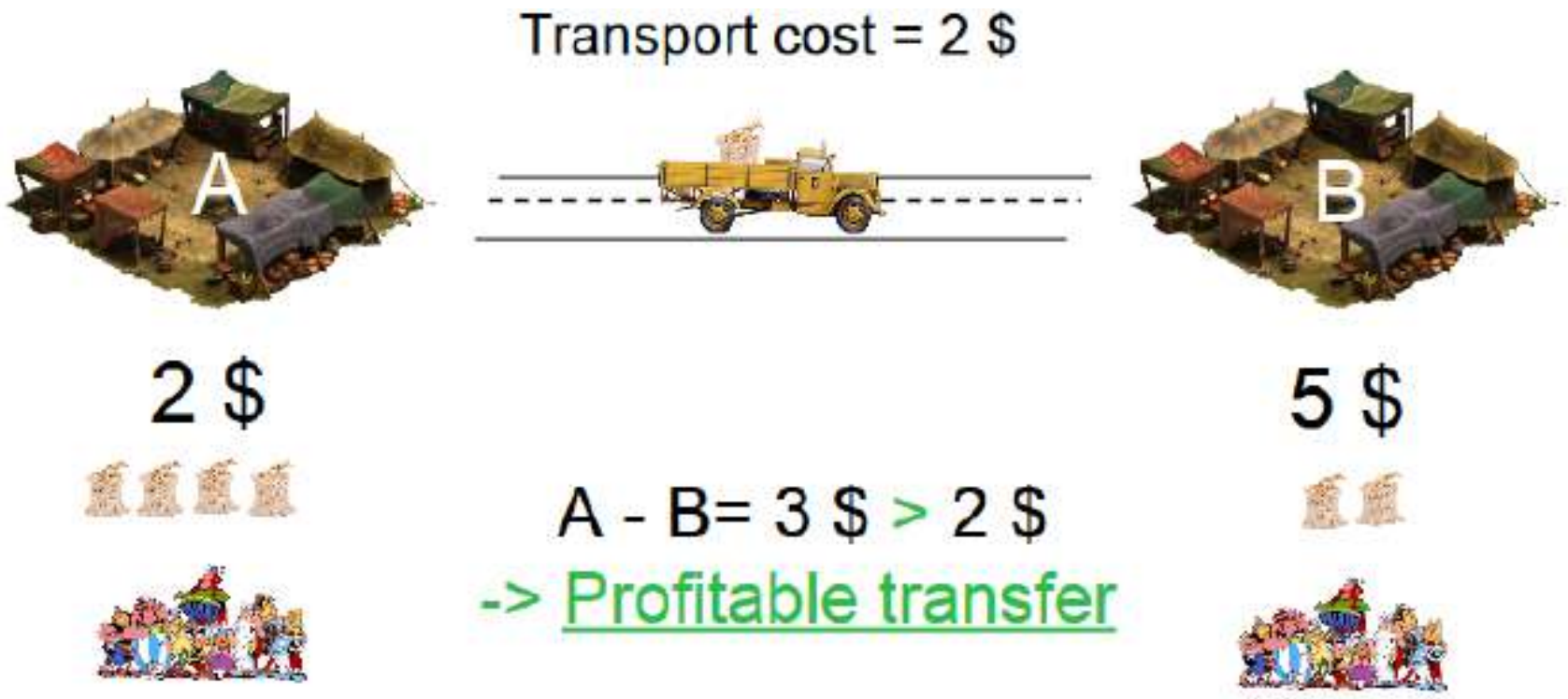

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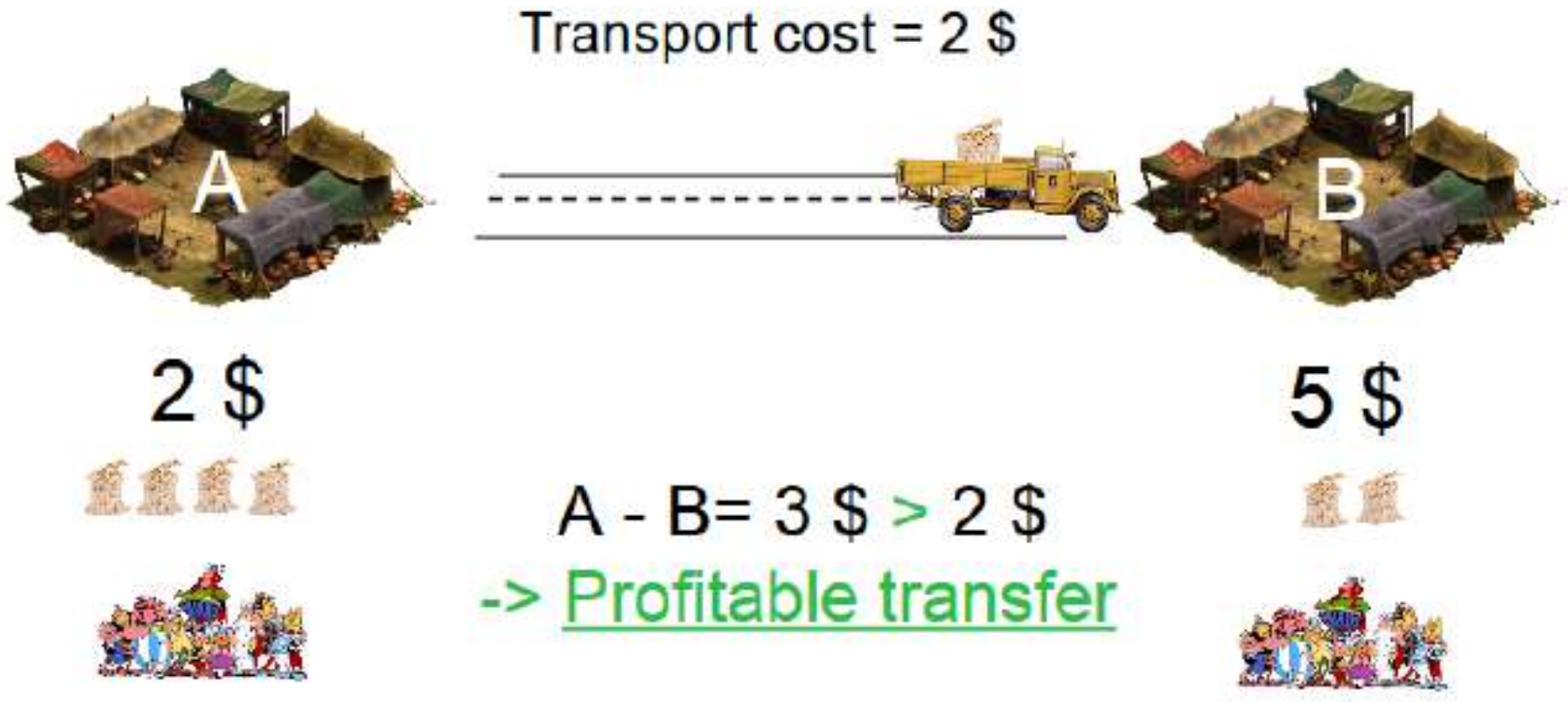

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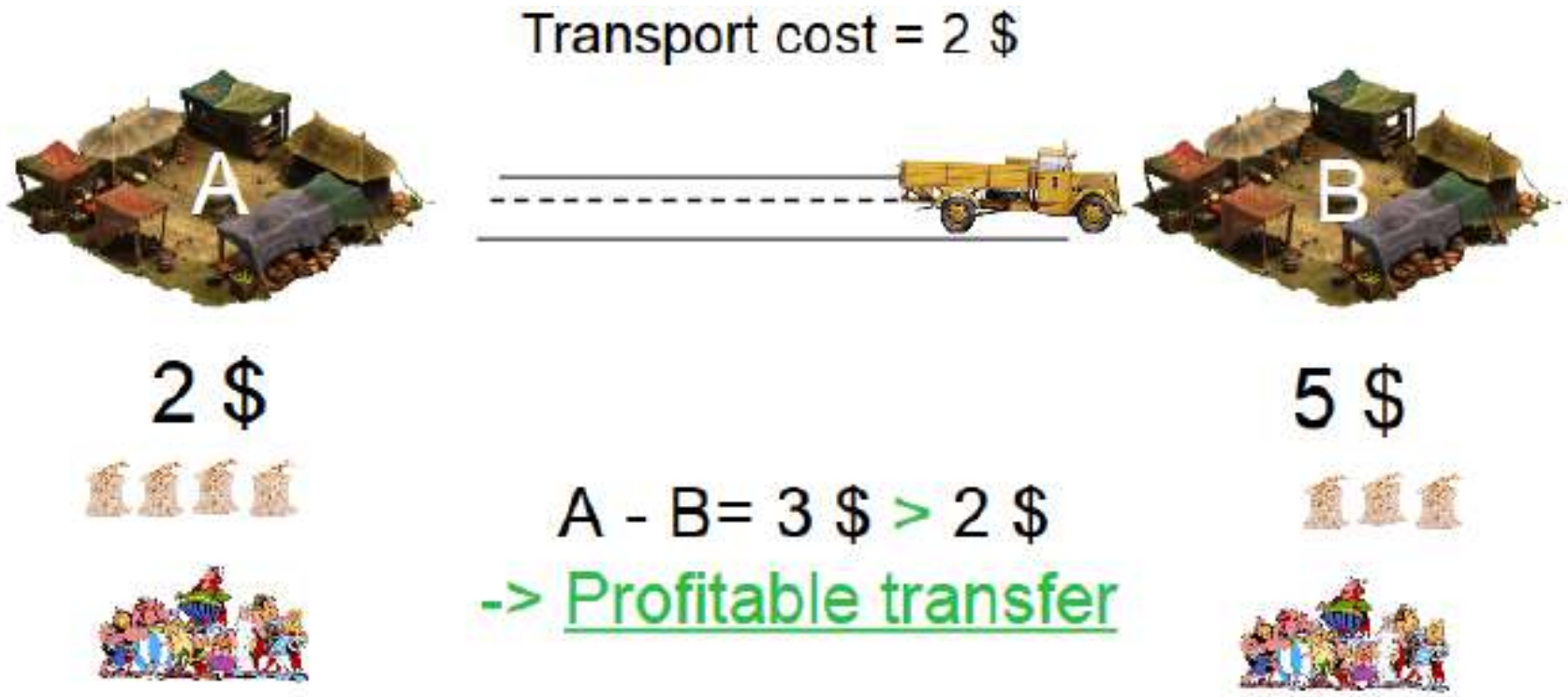

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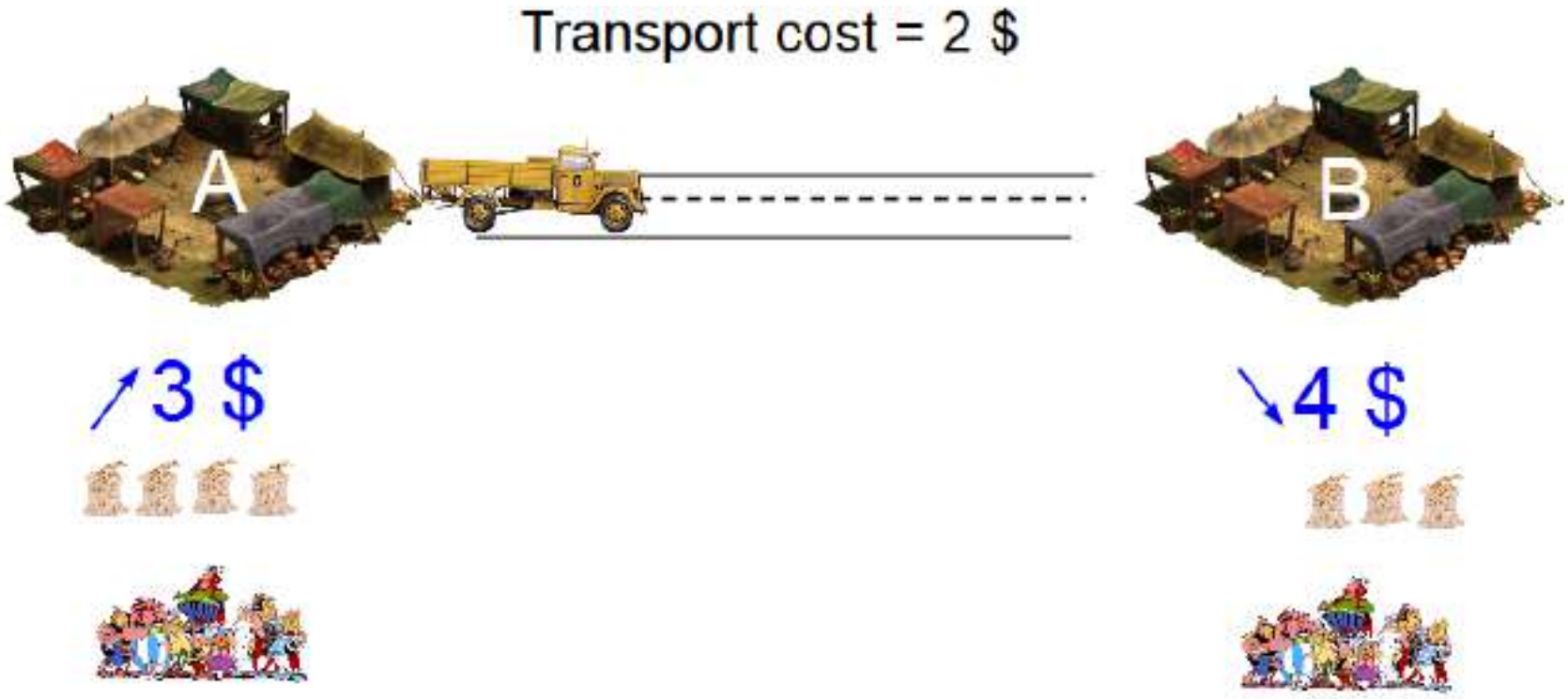

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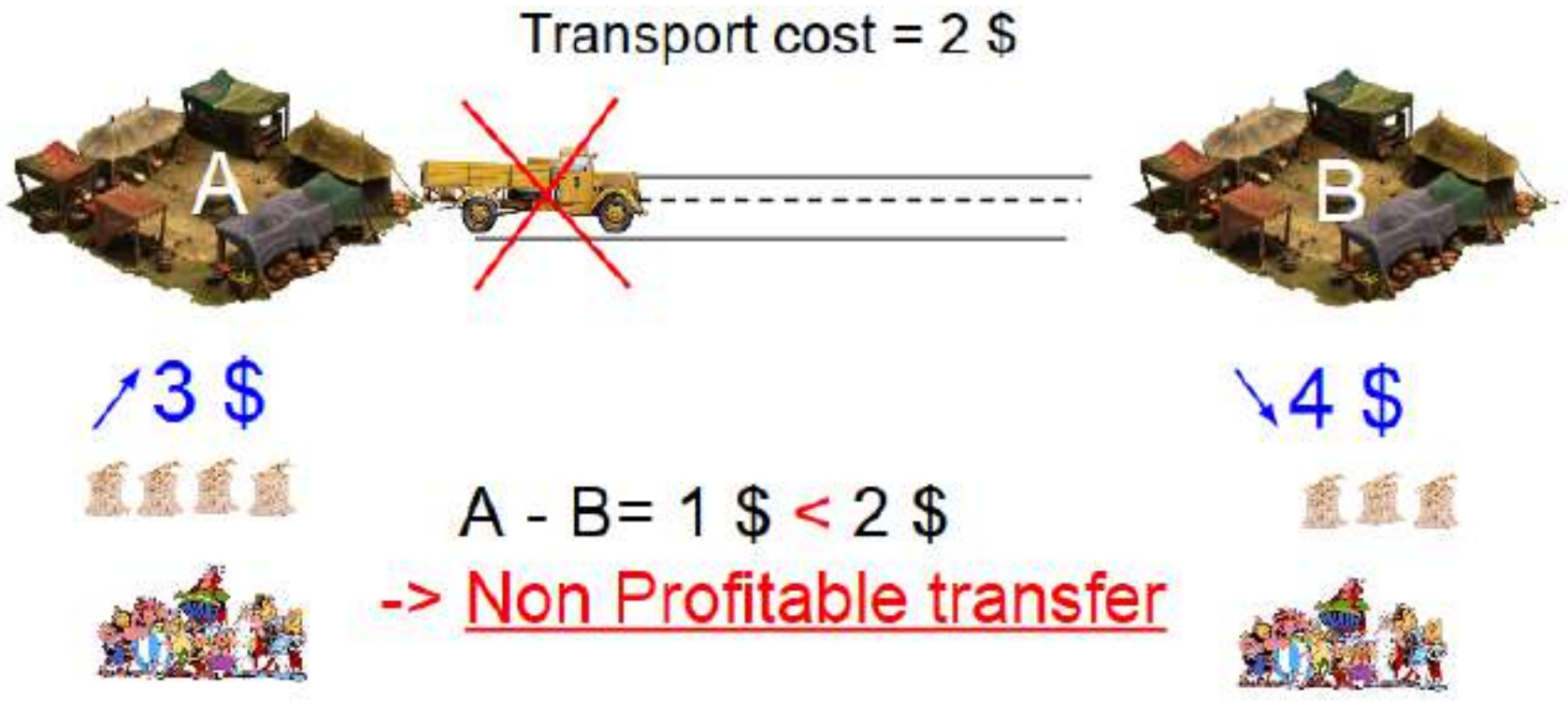

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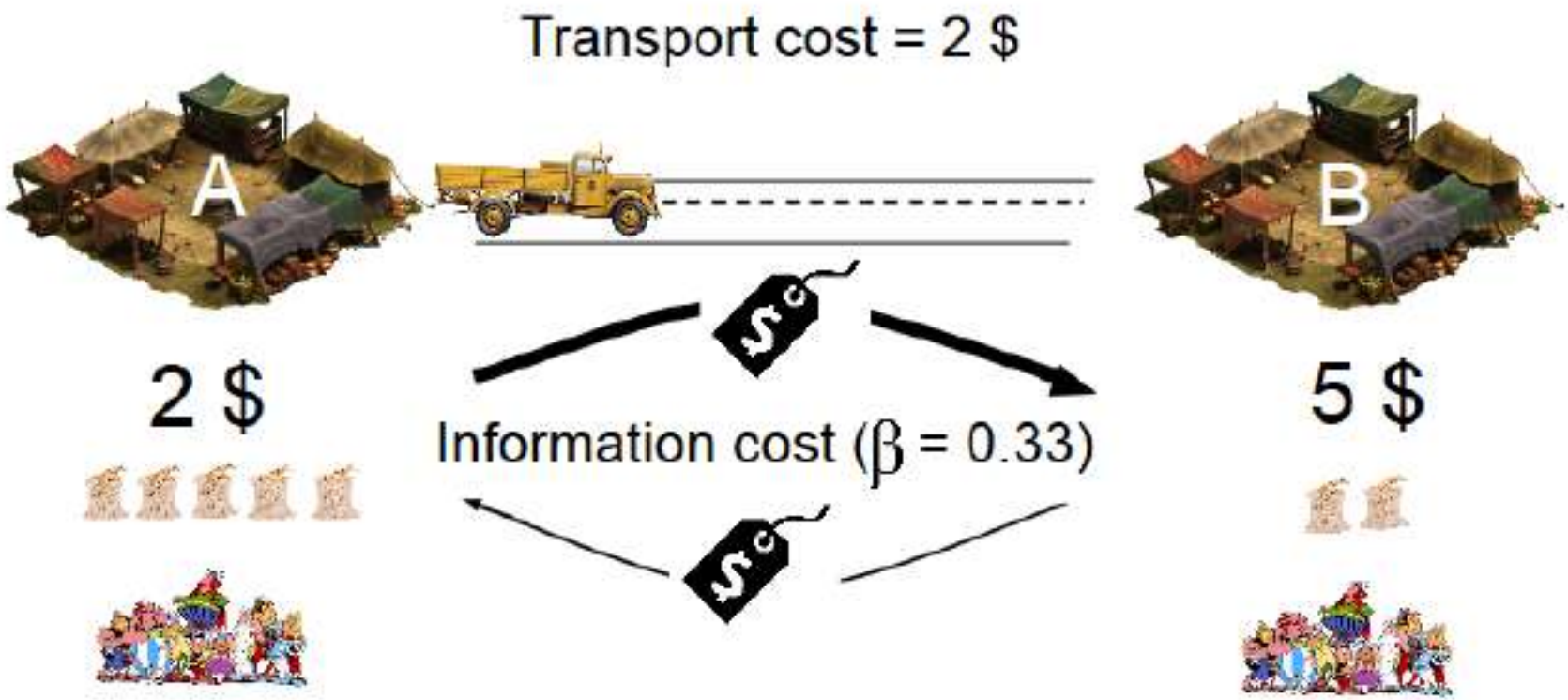

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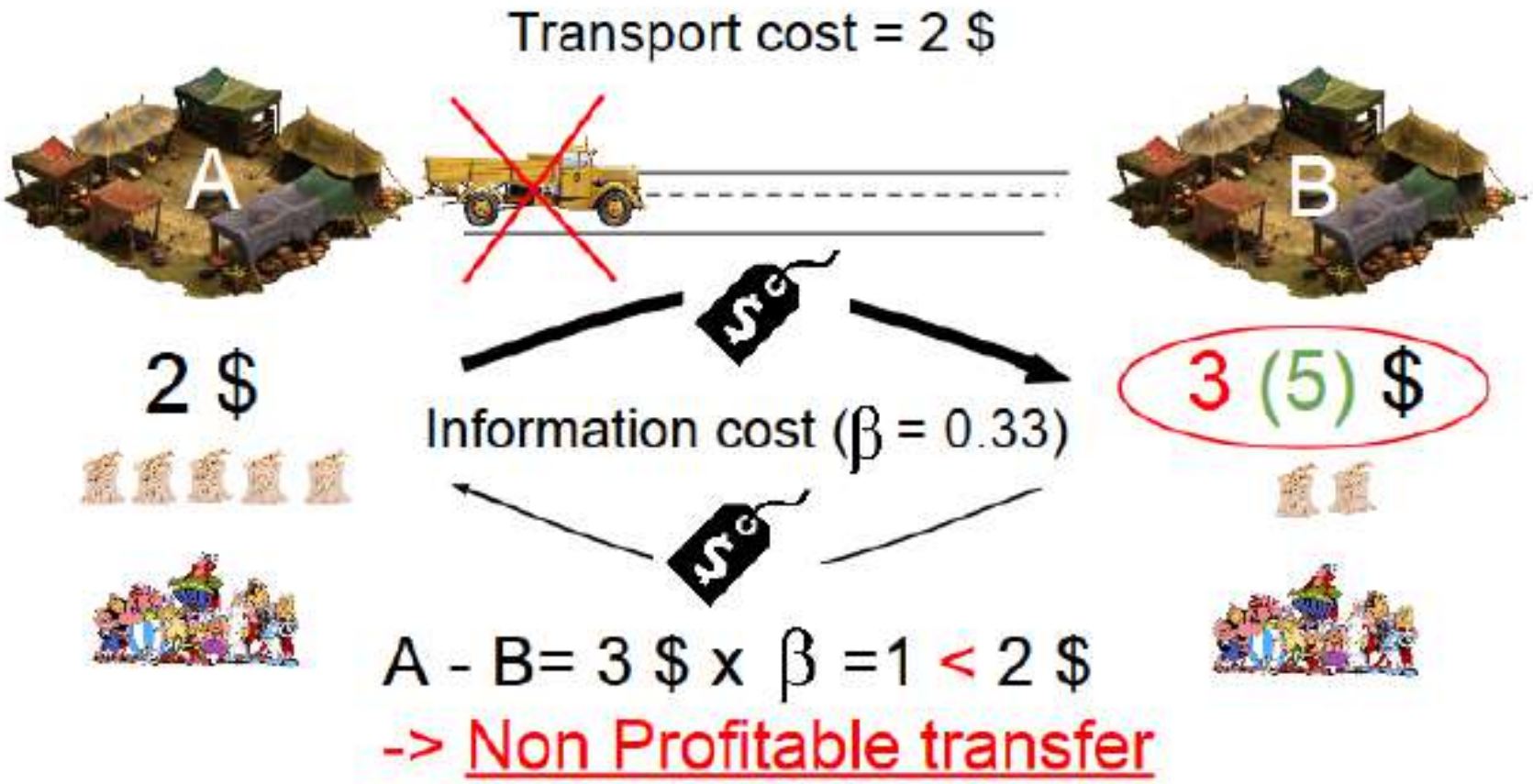

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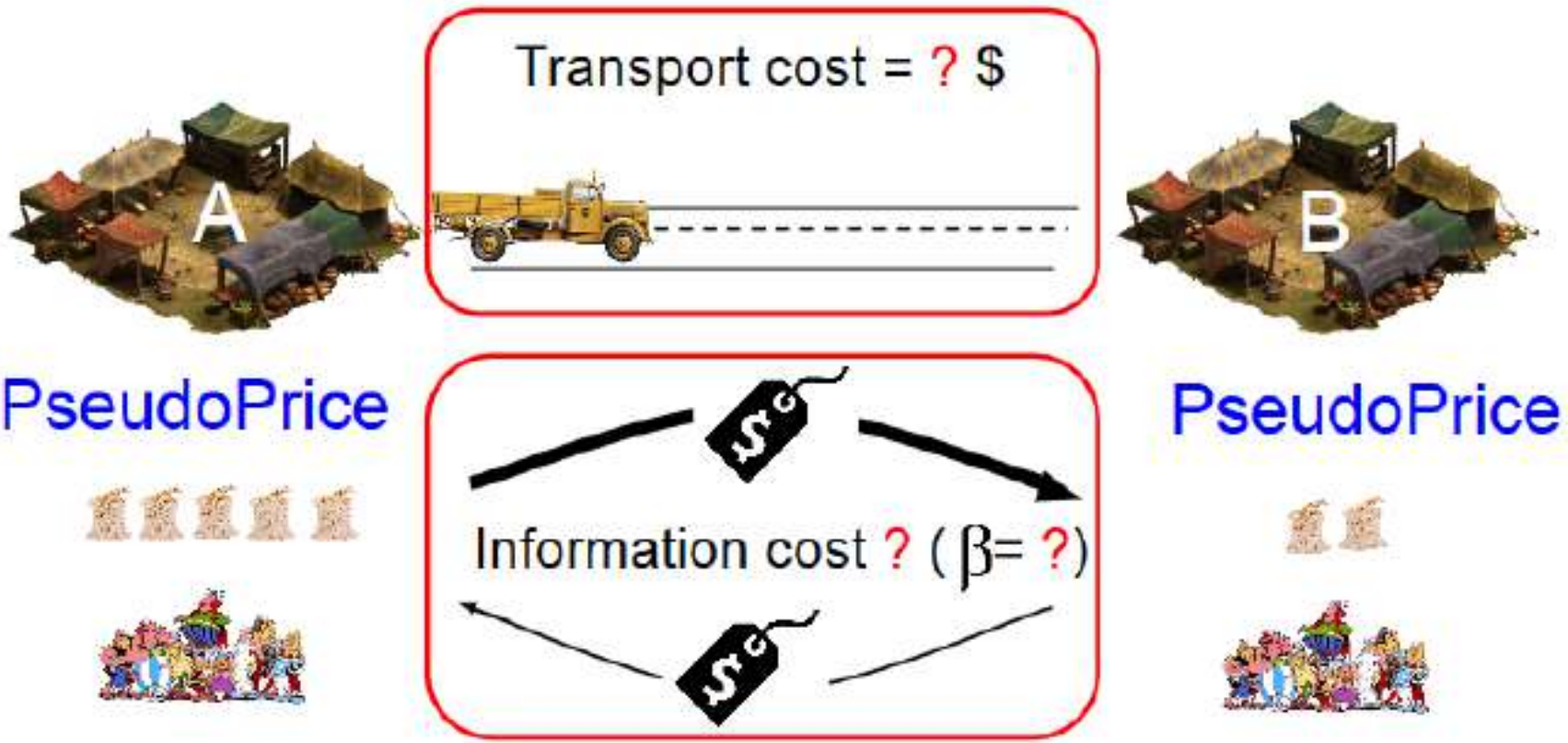
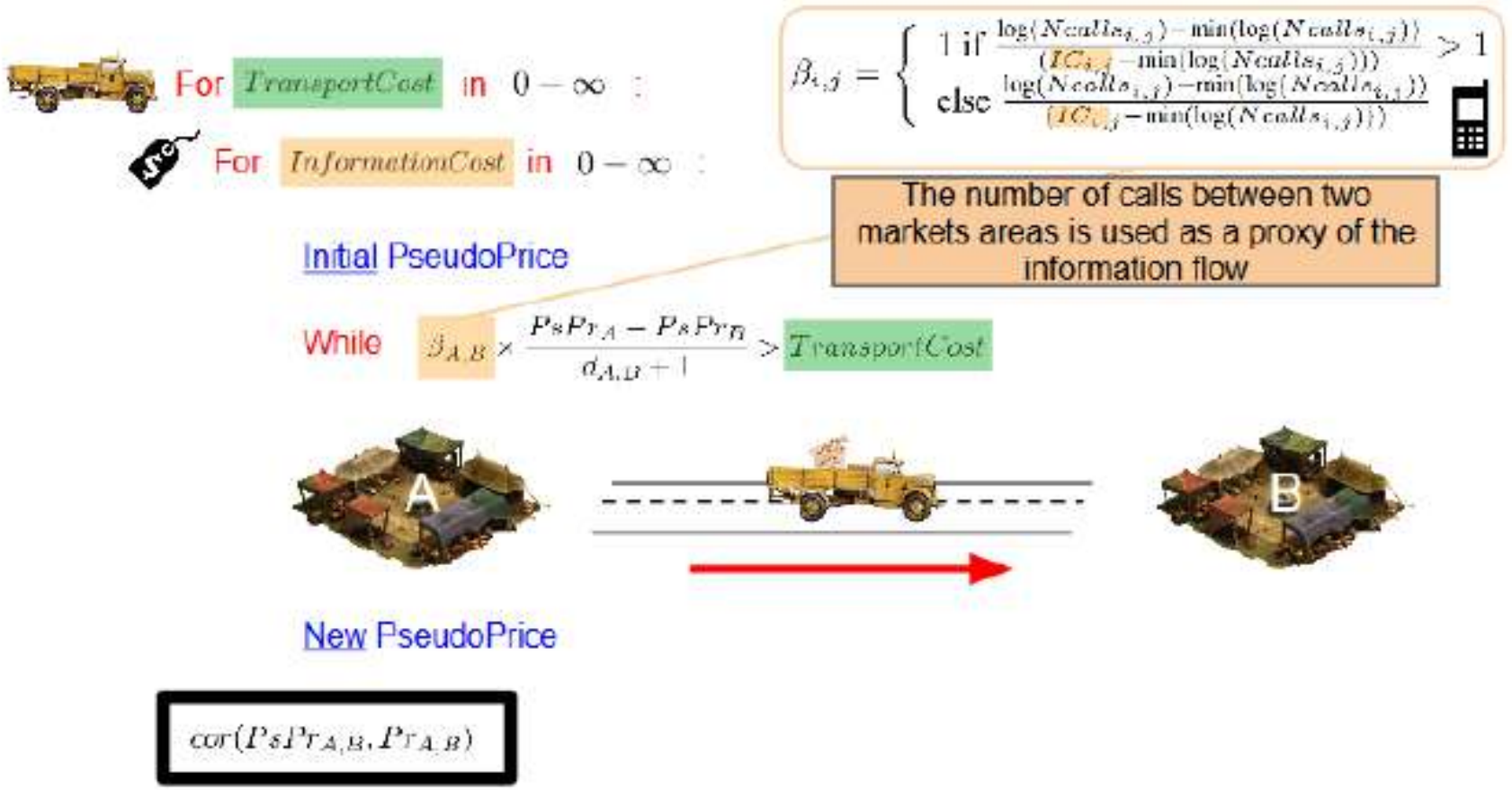


The model test a range of transport and information cost



Already widespread coverage of mobile phone network in the country

Senegal - Mobile cellular subscriptions per 100 inhabitants

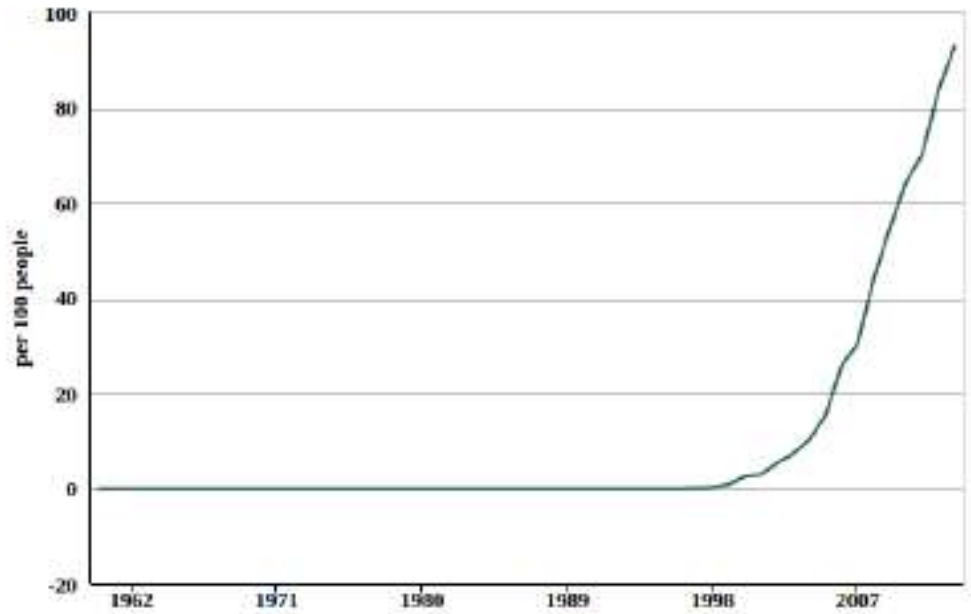
92.9

(subscriptions per 100 inhabitants)

in 2013

Mobile cellular telephone subscriptions are subscriptions to a public mobile telephone service using cellular technology, which provide access to the public switched telephone network. Post-paid and prepaid subscriptions are included.

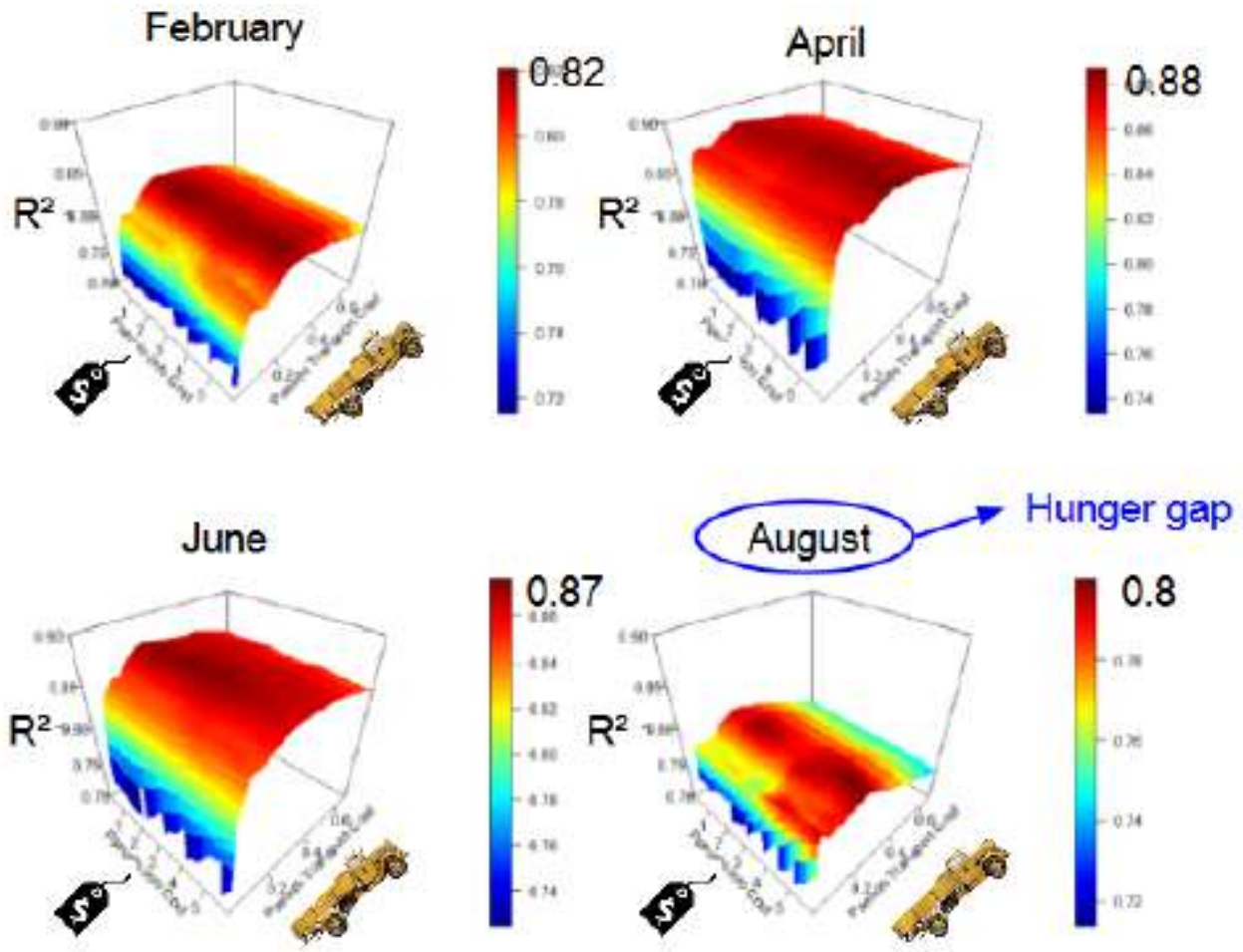
Compare | Export | Explore data | Embed | View Ranking | View Map | Add to Gadget Bin



Date	Value	Change, %
2013	92.9	11.20 %
2012	83.6	19.11 %
2011	70.2	8.90 %
2010	64.4	17.50 %
2009	54.8	24.52 %
2008	44.0	44.38 %
2007	30.5	18.44 %
2006	25.8	67.75 %
2005	15.4	50.14 %
2004	10.2	39.47 %
2003	7.3	37.62 %
2002	5.3	

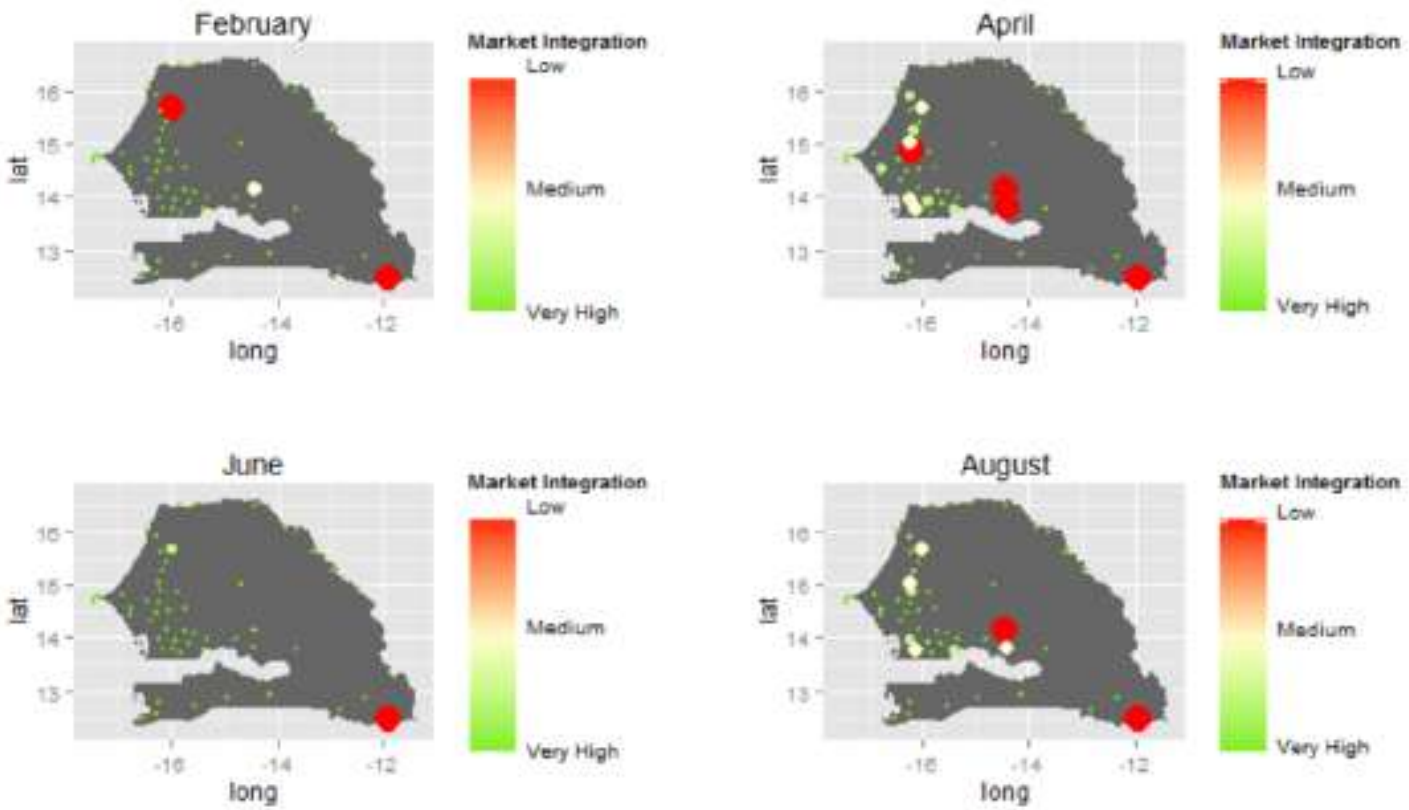
Source: World Development Indicators (WDI), September 2014

Really good results (R^2=**0.8-0.88 !!**) up to **10 months** after the harvest

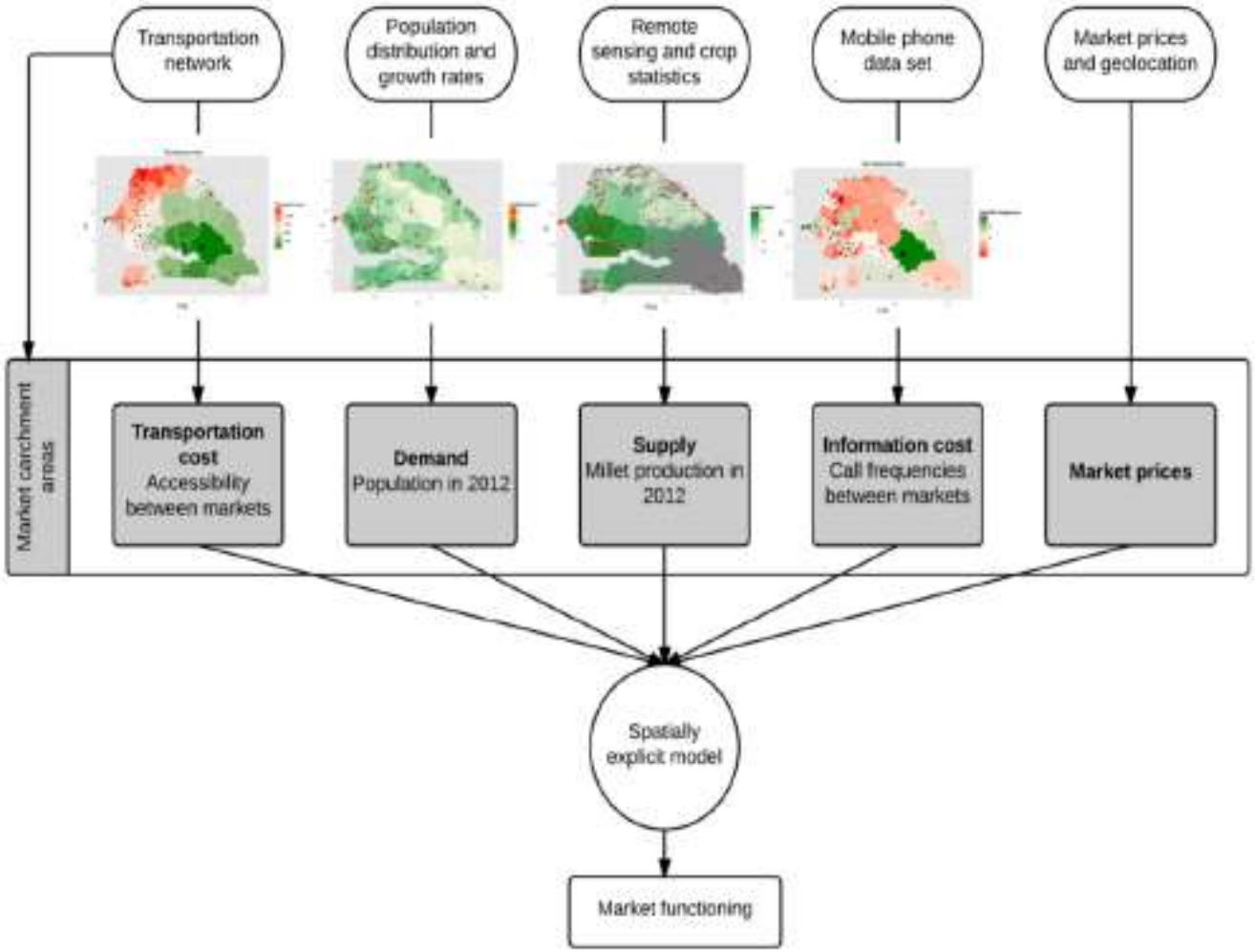


β, an indicator of market failure

- Market integration defined by mobile phone data (number of markets with a $\beta < 1$ for the best modelling in February, April, June and August)



A spatial explicit model with various sources of data



To conclude

- This pioneer work opens a new avenue for:
  - the already rich literature on **market integration**
  - the integration of the two first pillars of **food security**, i.e. availability and access
  - the development of the food security **early warning systems** in the region
- New findings are expected from the use of **several years** of mobile phone data and the expansion of the model to **other Sahelian countries**.

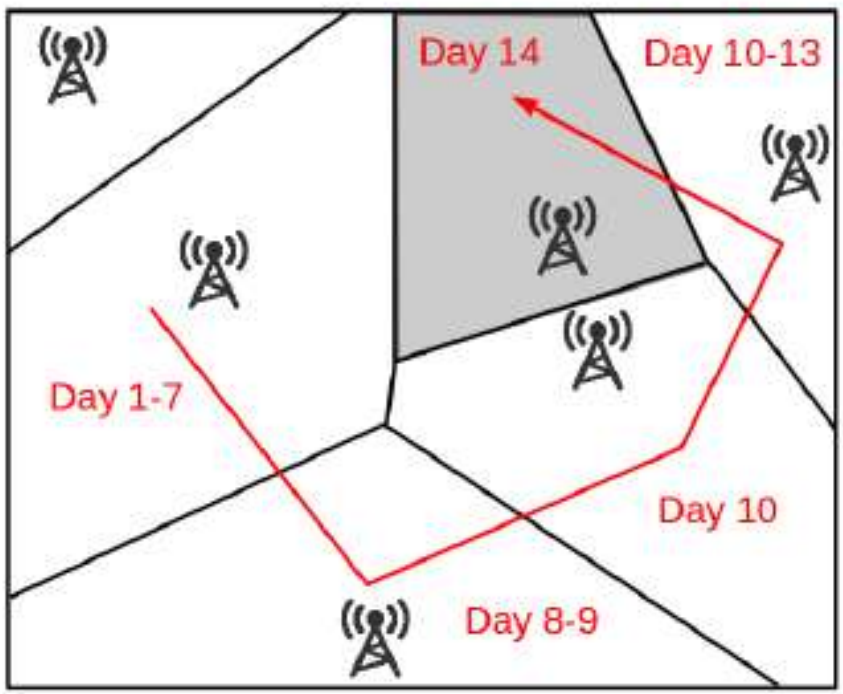
We are going to Senegal in one month

BILL & MELINDA GATES foundation

UCL Université catholique de Louvain

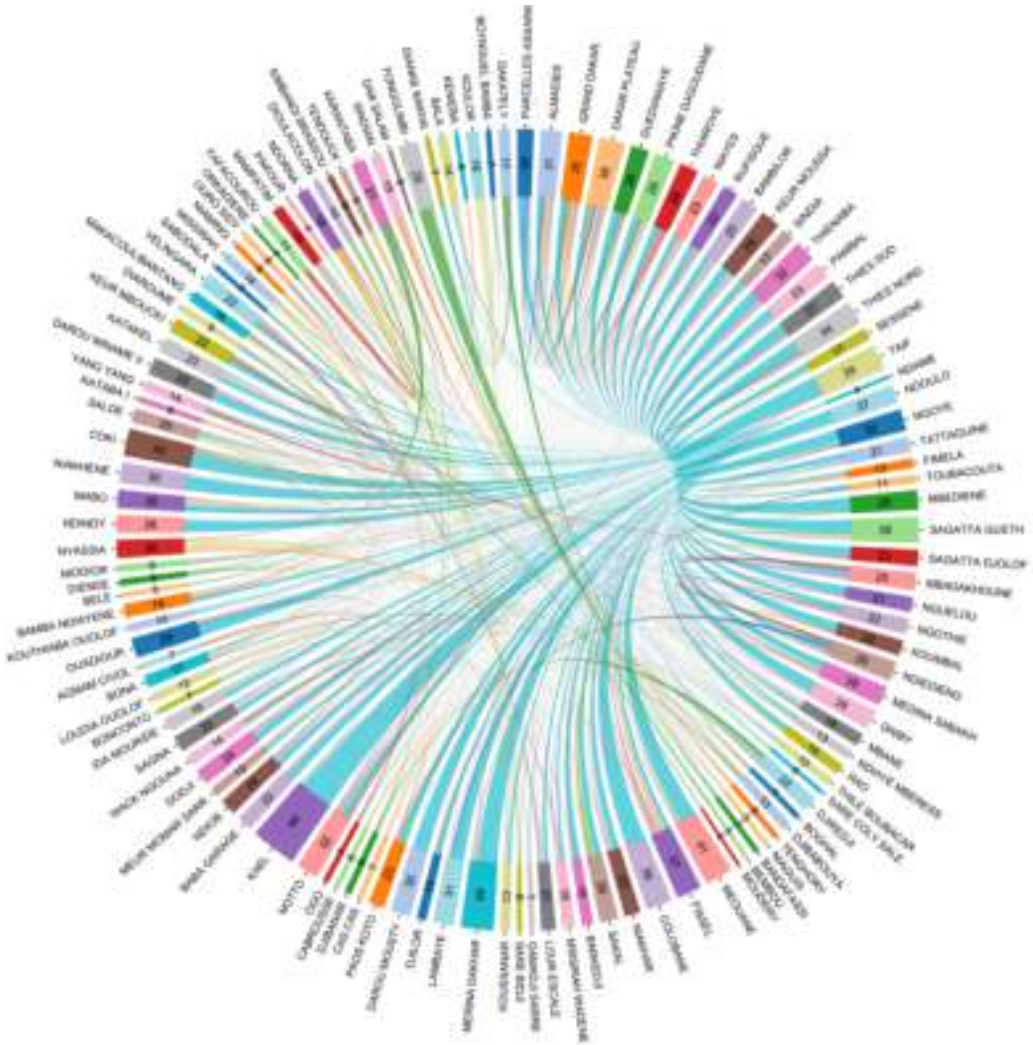
Dataset 2: Fine-grained mobility

At site level,

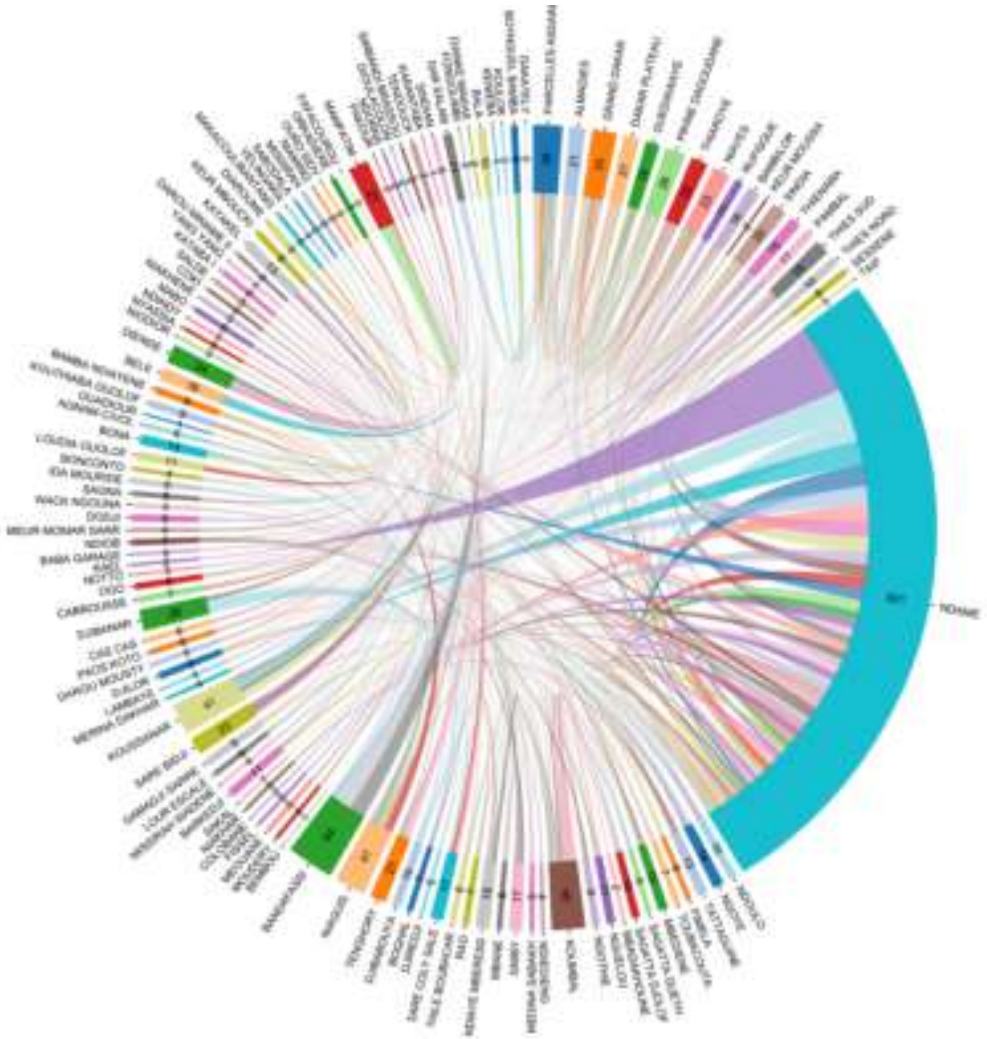


Every 2-weeks, new sample: 300 000 users

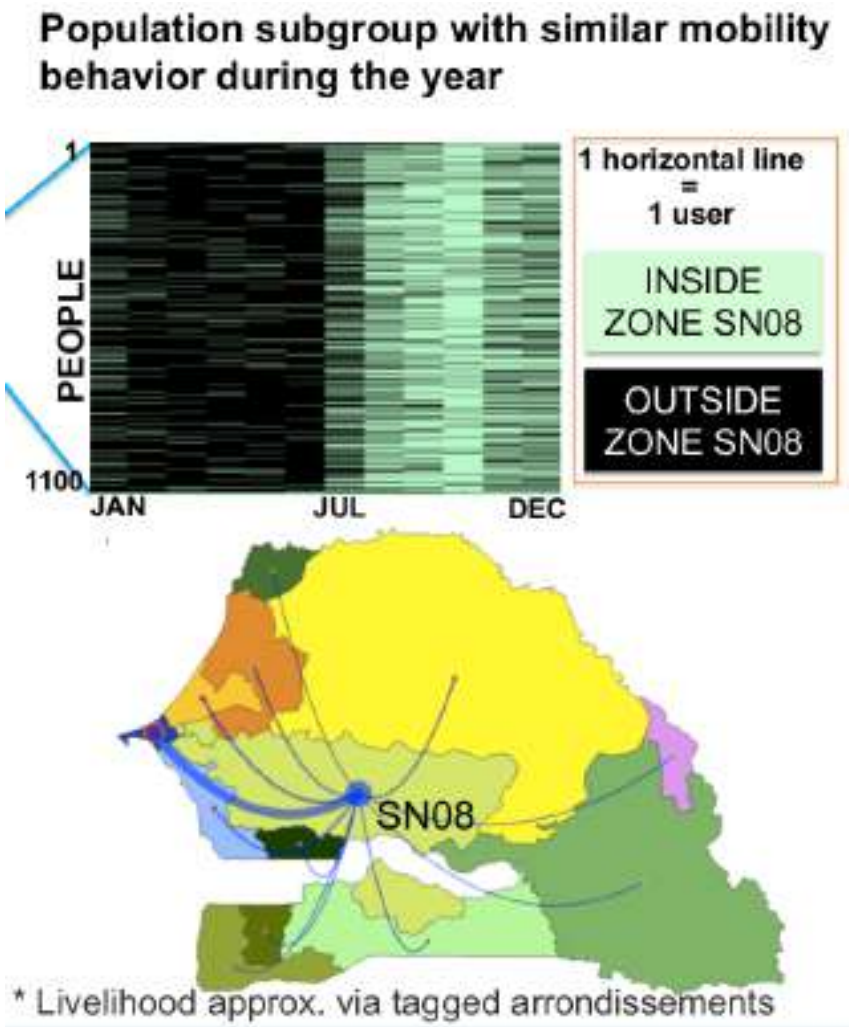
Grand Magal detection on the 21st of December 2013



Grand Magal detection on the 21st of December 2013



Mobility profiles linked with agricultural calendar



Mobility profiles linked with agricultural calendar

Zone 8: Agro-pastoral Peanut Zone

Source of income/activity	January	February	March	April	May	June	July	August	Septembe	October	November	December
millet, cowpea, watermelon												
Peanuts												
Maize												
Sorghum												
Cattle/poultry sales												
Baobab gathering												
Jujube gathering												
Salt harvesting												
Market gardening												
Transhumant livestock rearing												
Trade												
Crafts												
Seasonal migration												
International migration												
Local labor												

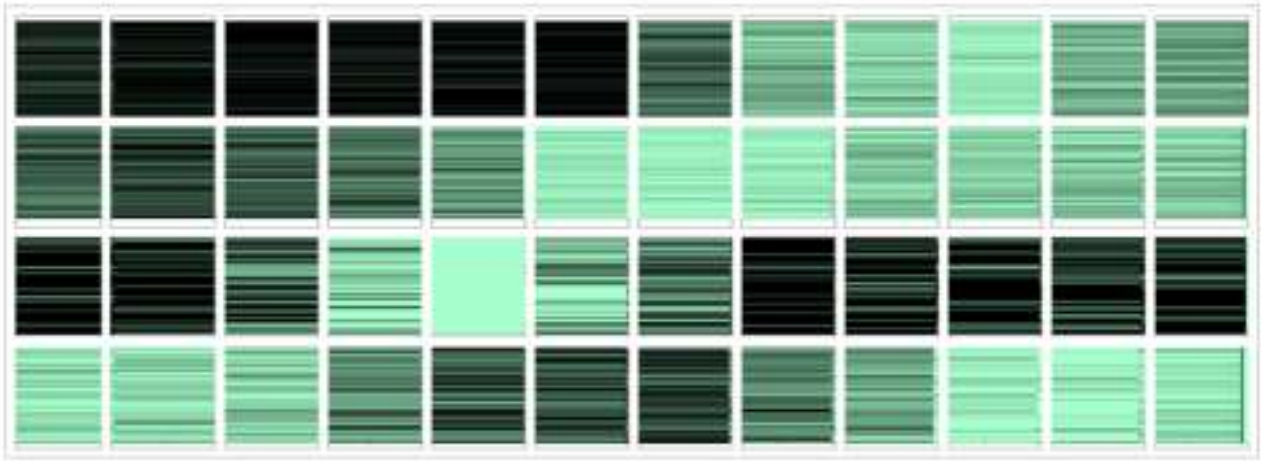


Figure 11. Zone 8 calendar of sources of income and activities against users' mobility profiles.

Mobility profiles linked with agricultural calendar