Importance of oil palm:

- Cooking products

- Cleaning products

- Special greases and lubricants

- Personal hygiene and cosmetics

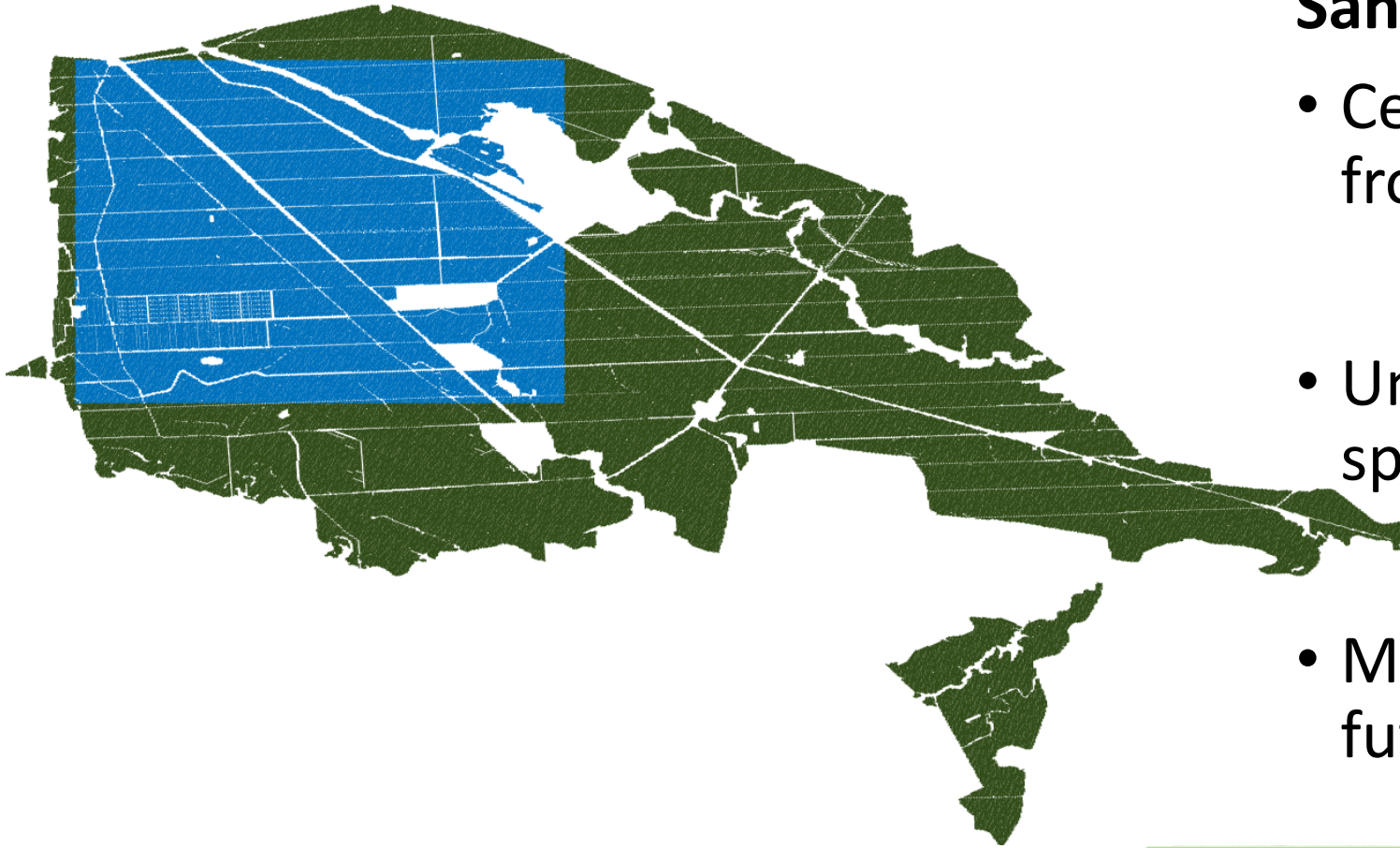- Production of biodiesel and electrical energy

- Pharmaceutical

What is the issue with Lethal Wilt ?

- Infectious vector not fully determined yet

- Loss and delay of production and increased insurance premiums

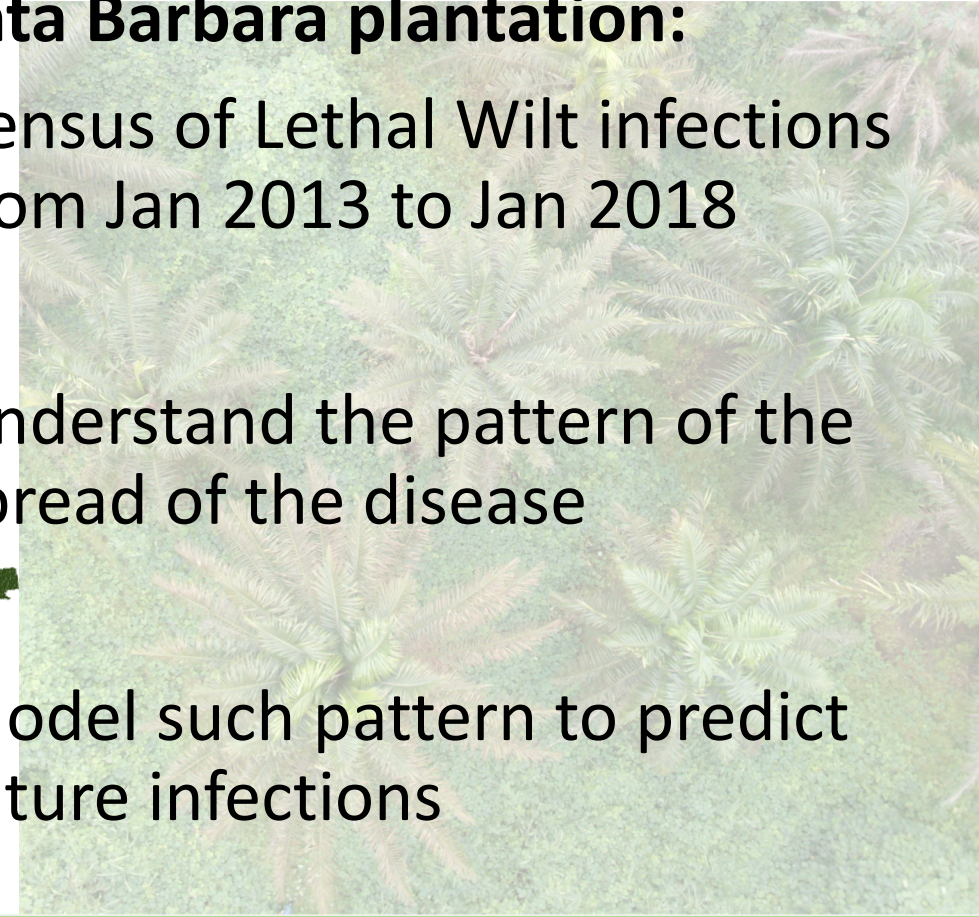- Detrimental to sustainable production

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Data used and Objectives

Santa Barbara plantation:

- Census of Lethal Wilt infections from Jan 2013 to Jan 2018

- Understand the pattern of the spread of the disease

- Model such pattern to predict future infections

Sustainable agriculture

- The plantation is on land used previously for other crops, no deforestation

- Maximizing the production of the plantation allows for sustainable growth with no deforestation or increasing more land used

- Modelling enables this

Related work

Modelling in agriculture has increased significantly in applications that support sustainability and efficiency:

- Work has been done to model biodiversity vs. income to small producers studying synergies between development and conservation

- Remote sensing supports optimisation of crop management

- Many works use agents to model epidemiological processes.

Collating and organising the data

- We chose a square section of the plantation's census data, and organised it in a grid of NxN cells

- We performed the analysis of different granularities to determine if a consistent pattern could be identified

- We analysed the frequency of reinfection in each cell and in its neighbours

- The result are consistent at each granularity level thus confirming the spread is local

TABLE I
CELL RISK OF INFECTION AT VARYING GRANULARITIES (WINDOWS = 6)

Grid	RI	PNI	ANI	NI	NNI
8^2	0.94	0.83	0.99	0.56	0.04
16^2	0.67	0.64	0.95	0.33	0.14
32^2	0.4	0.38	0.71	0.15	0.08
64^2	0.1	0.1	0.28	0.05	0.03

TABLE II
CELL RISK OF INFECTION AT VARYING WINDOWS (GRANULARITY = 32^2)

Window	RI	PNI	ANI	NI	NNI
1	0.15	0.13	0.14	0.06	0.05
3	0.28	0.27	0.54	0.11	0.07
6	0.4	0.38	0.71	0.15	0.08
12	0.57	0.53	0.86	0.02	0.08

Modelling the infection path

We propose a multi-agent based approach

- Agents take a directed walk from all newly infected cells, and predict the spread based on the cells where these agents end and the number of times each cell is visited

$$\hat{f}(x) = \frac{1}{N} \sum_{i=1}^{n} K\left(\frac{x - x(i)}{h}\right)$$

- There are two stages to the proposed model:

- With Kernel Density Estimation (KDE) areas with more infections have a higher density, directing agent's walk

$$P_{cn_i} = \frac{d_i}{\sum_{j=1}^{8} d_j}$$

- Subsequently, each agent is biased to walk 'uphill' towards denser areas

Metrics

We evaluate the performance in terms of True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN)

- We evaluate the precision *P* of the model:

$$P = \frac{TP}{TP + FP}$$

- The model's recall score *R:*

$$R = \frac{TP}{TP + FN}$$

- And the *Rand Index* **RI** which is essentially the overall accuracy of the model:
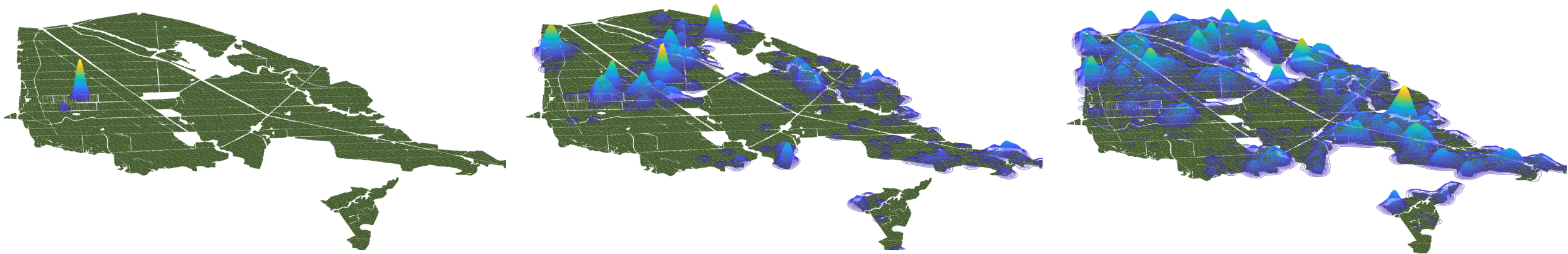
$$RI = \frac{TP + TN}{TP + FN + TN + FN}$$

Results

The modelling is done comparing to the ground truth distribution from the census of infection densities, estimated to the final time-step as below

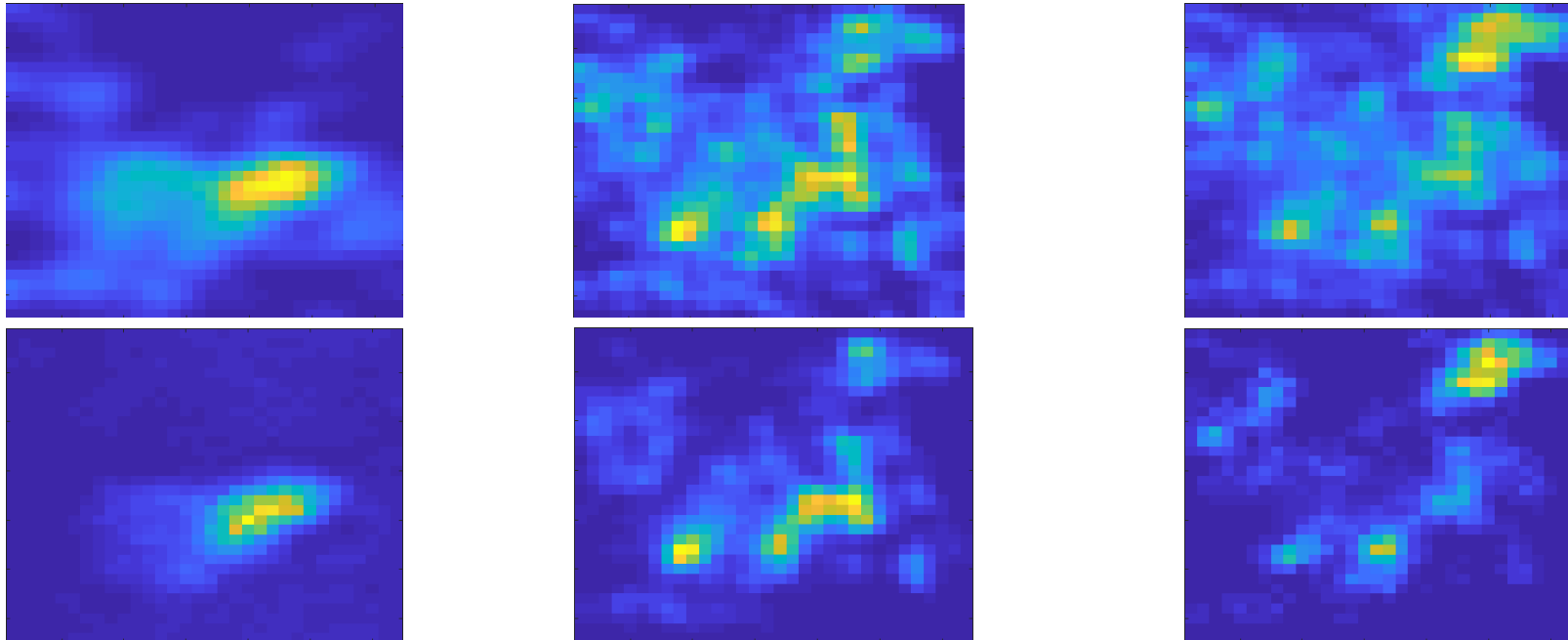Due to the stochastic nature of the model, for each experiment we present the mean (and deviation) of 100 runs

Results

For 60 agents taking 3 steps and a threshold value of 1.5 the model achieves 69% precision (±0.002), 75% Recall (±0.001) and a Rand Index of 74% (±0.001).

The month to month accuracy compared visually, actuals above and models below

Conclusions

- Our analysis shows that the disease is much more likely to spread to a local area (for example through insect vectors) rather than a far-way area (for example, via an airborne vector)

- The direction and severity of the spread is an emergent consequence, a result of a local 'build-up' of infections, forming isolated clusters

- The data confirms the intuition, though modelling this process is difficult due to the frequently stochastic behaviour of the process

- In the future we will try other agent-based models, e.g. agents that can learn from previous decisions as opposed to a biased-walk directed only