LAND USE MODELLING IN THE DUTCH LIMES

A COMPARISON OF APPROACHES

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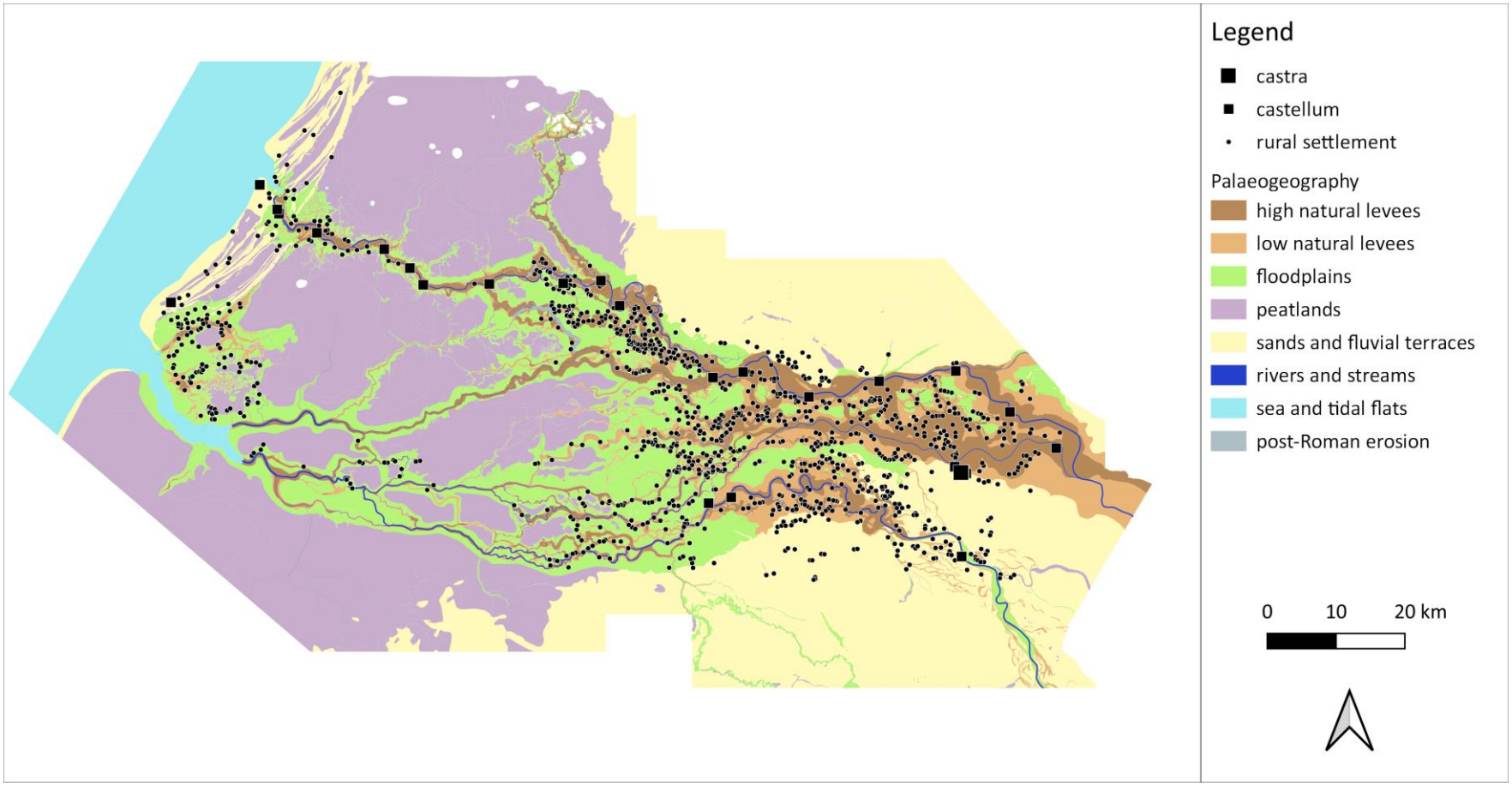
INTRODUCTION

- in this paper
  - we compare two approaches to model the impact of settlement on land use in the Roman period in the Dutch river area: the **Past Land Use Scanner (PLUS)** and **ROMFARMS**
  - we discuss issues of scale, temporal resolution and model inputs, together with questions of technical implementation and validation
  - how should we evaluate the model outcomes? what are the advantages and limitations of each?

THE DUTCH *LIMES* (15 BCE – 275 CE)



THE SURPLUS QUESTION

"Batavian lands were never able to provide the necessary food for all the soldiers stationed there [the limes region]"

Willems, W.J.H. 1986. *Romans and Batavians. A Regional Study in the Dutch Eastern River Area*, p.424

"No local community could suddenly have started to produce the surplus required to feed the troops"

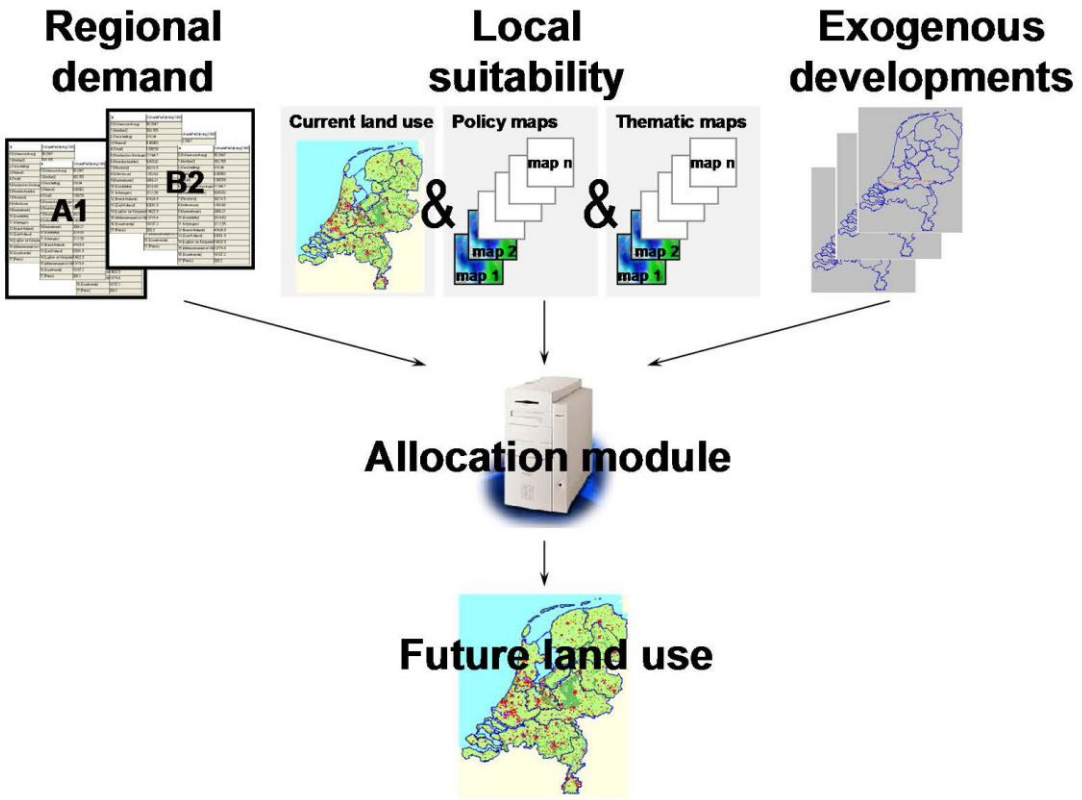
Whittaker, C.R. 2004. *Rome and Its Frontiers*, p. 104

"The total rural population, even estimated at a minimum, was also able to produce enough surplus cereals, e.g. emmer and barley, to fulfil the demand of the Roman army and its associates for these cereals"

van Dinter, M. et al. 2014. *Could the local population of the Lower Rhine delta supply the Roman army? Part 2*, p. 32

PLUS (PAST LAND USE SCANNER; DE KLEIJN ET AL. 2018)

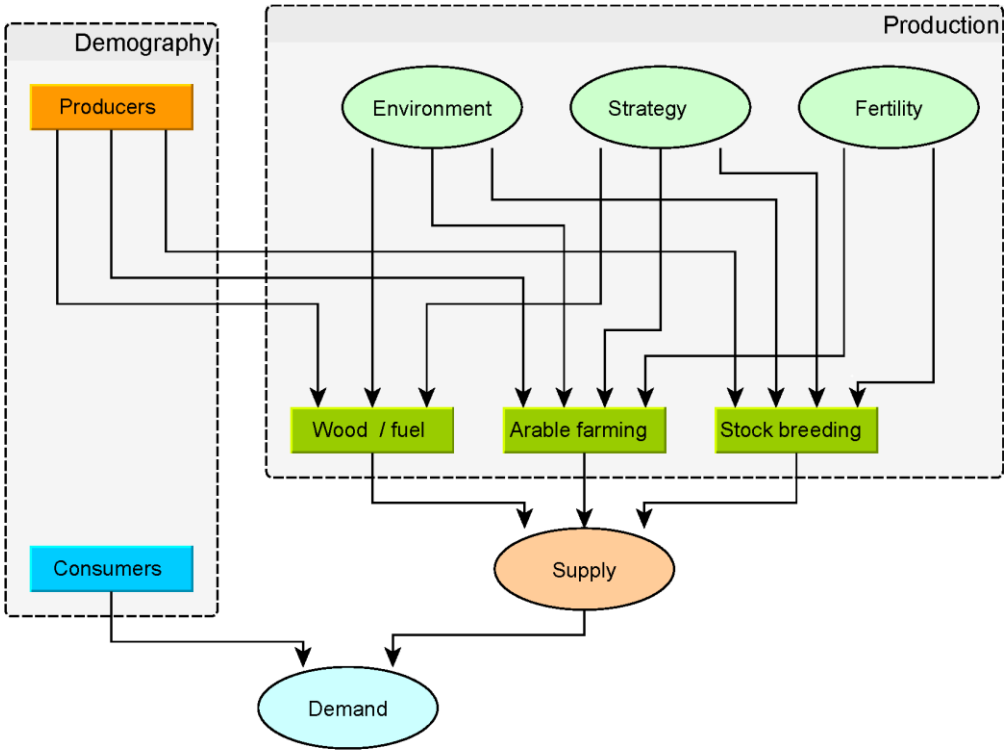
- simulates Roman land use by comparing supply and demand of land
- equation-based
  - efficient raster calculations
- predictive purpose
  - originally designed for modern planning



Koomen 2016

ROMFARMS (JOYCE 2019)

- simulates interplay and dependencies of factors in Roman agricultural production
- agent-based model
  - combined with system dynamics modelling
- heuristic purpose
  - predict agricultural yields under a wide range of scenarios



CRITERIA FOR MODEL COMPARISON

- technical
  - software and computational resources required
  - reproducibility and ease of use
- methodological / conceptual
  - underlying mechanisms and theoretical frameworks
  - spatial and temporal scope
- application
  - assumptions for models and experimental runs in relation to outcomes
- outcomes and validation
  - internal consistency and comparison to archaeological insights

TECHNICAL

- PLUS
  - **GeoDMS**
    - process and visualize large geographic datasets
    - often used in conjunction with GIS
    - limited programming options
- ROMFARMS
  - **NetLogo**
    - limited spatial analysis
    - extensive programming options
    - runs into computational limitations
- both are Free and Open Source Software

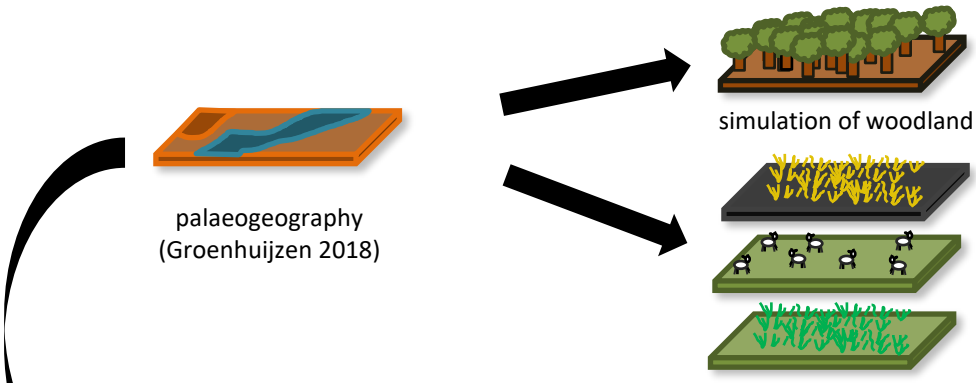
METHODOLOGICAL / CONCEPTUAL

Aspect	PLUS	ROMFARMS
Modeling approach	• discrete choice theory	• complex systems dynamics
Spatial Resolution	• 100 x 100 m grid	• 100 x 100 m grid • 10 x 10 km blocks
Temporal resolution	• **snapshots in time**	• **annual time steps** • scenarios run over 100 years
Spatial vs. non spatial	• non-spatial demand • spatial land suitability • competition for land • **spatial allocation of land use**	• spatial (local) demand • spatial land suitability • limited competition for land • **no spatial allocation of land use**

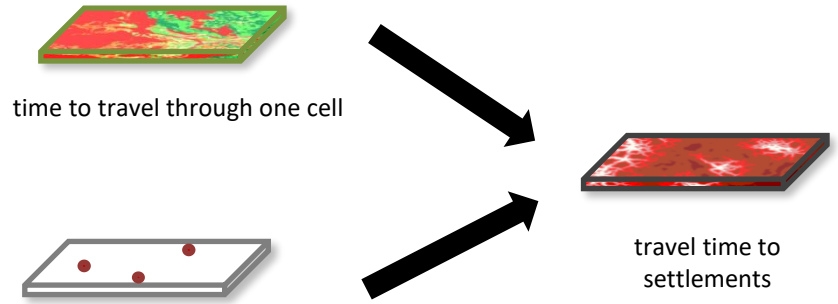
INPUTS

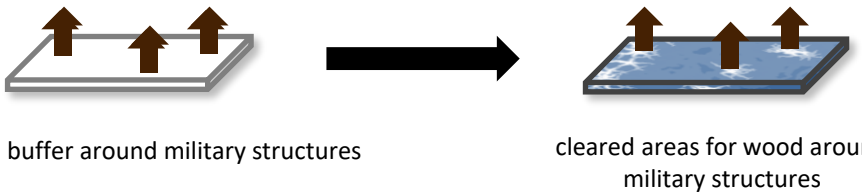
- model parameters
  - size of civilian and military population (consumers)?
  - size of rural population (workforce)?
  - proportion of calories obtained from cereals?
  - proportion of calories produced locally?
  - how much land was needed and available?
- data
  - typical size, number and dating of settlements
  - archaeobotanical and zooarchaeological evidence for diet and imports
  - land suitability

Physical suitability



Distance relationships

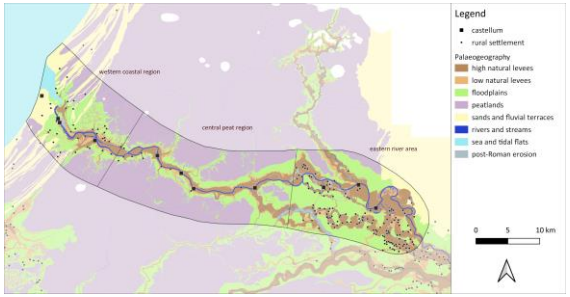




Political factors

140 CE: no imports from area north of the limes

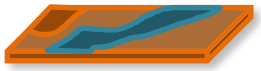
PLUS



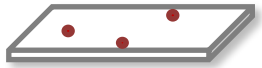
landuse
70 CE / 140 CE

ROMFARMS

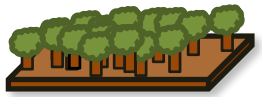
Physical suitability + demography



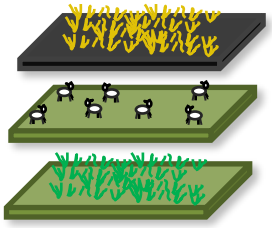
palaeogeography
(Groenhuijzen 2018)



settlements
(Verhagen et al. 2016)

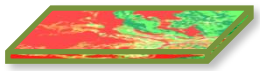


simulation of woodland

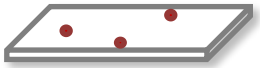


simulation of agrarian production

Distance relationships



nearest suitable cell



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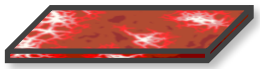


site catchments

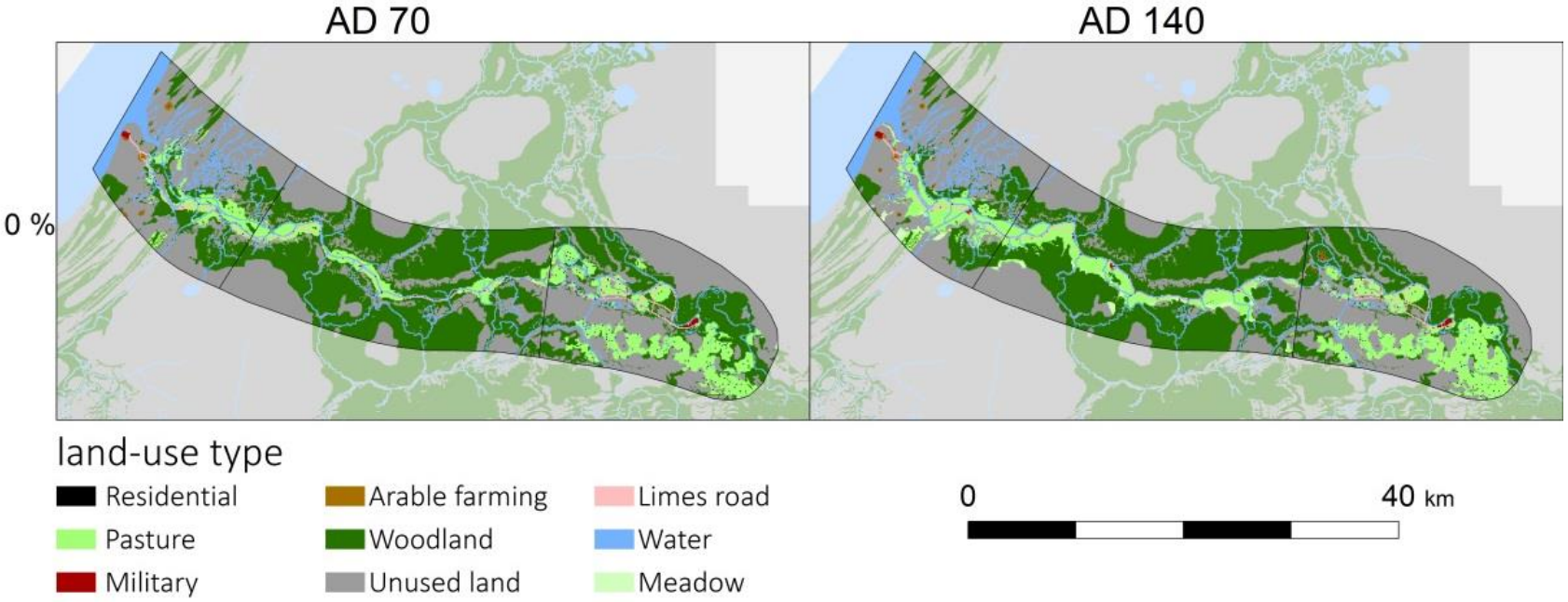
agrarian production
15 BCE – 275 CE

Technology factors

extensification or intensification

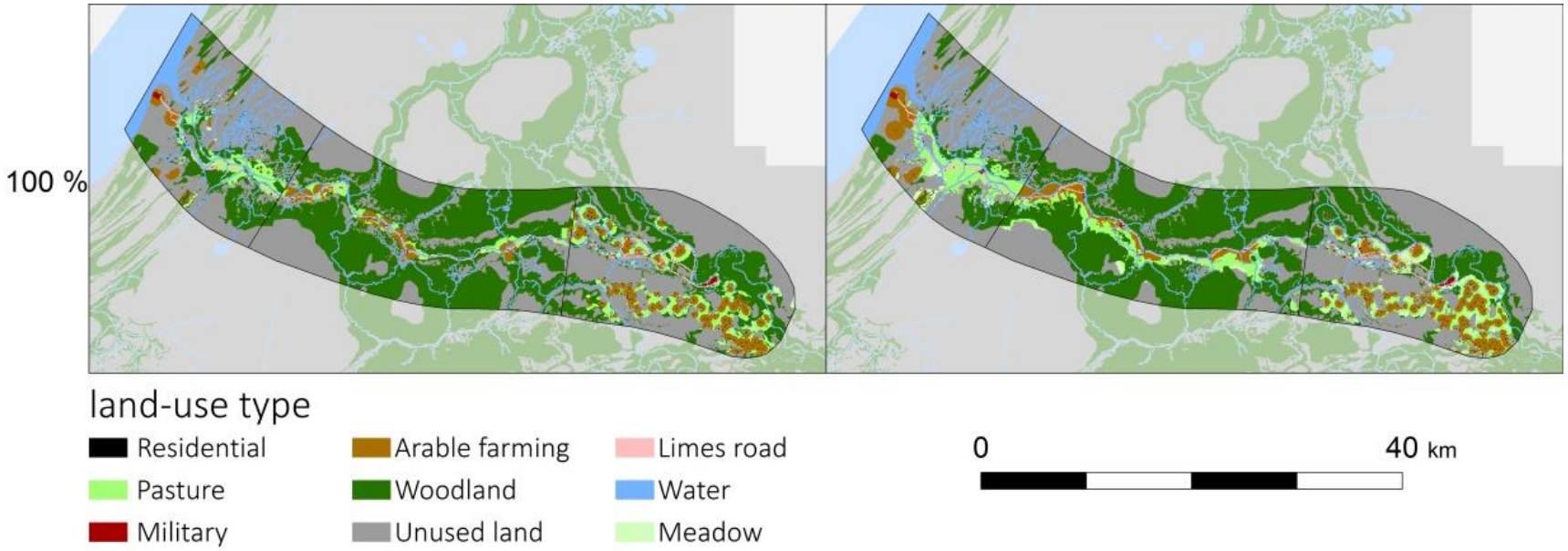
OUTCOMES (PLUS)

spatial prediction of land use,
depending on surplus production scenarios



OUTCOMES (PLUS)

spatial prediction of land use,
depending on surplus production scenarios



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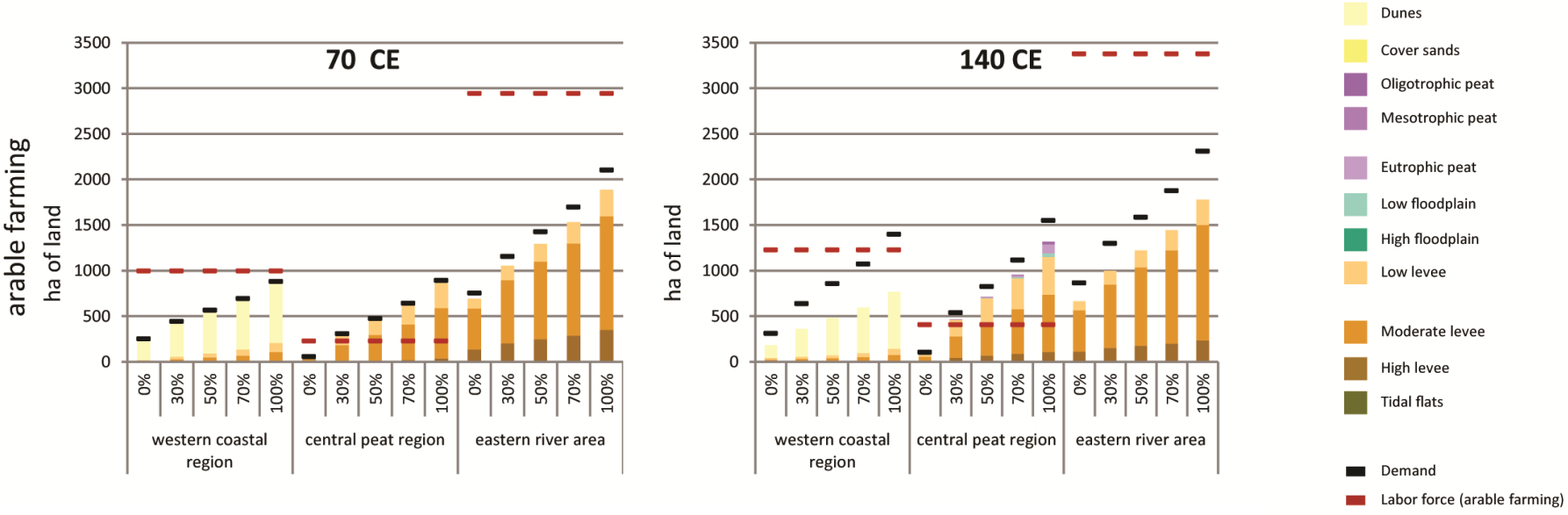
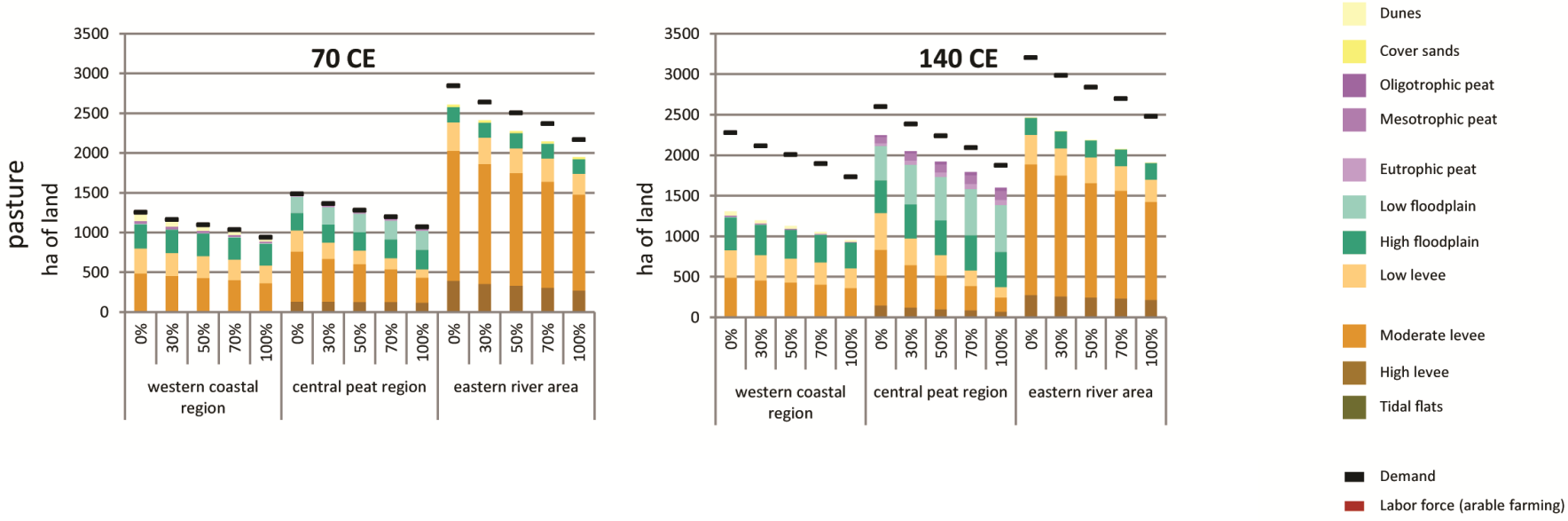


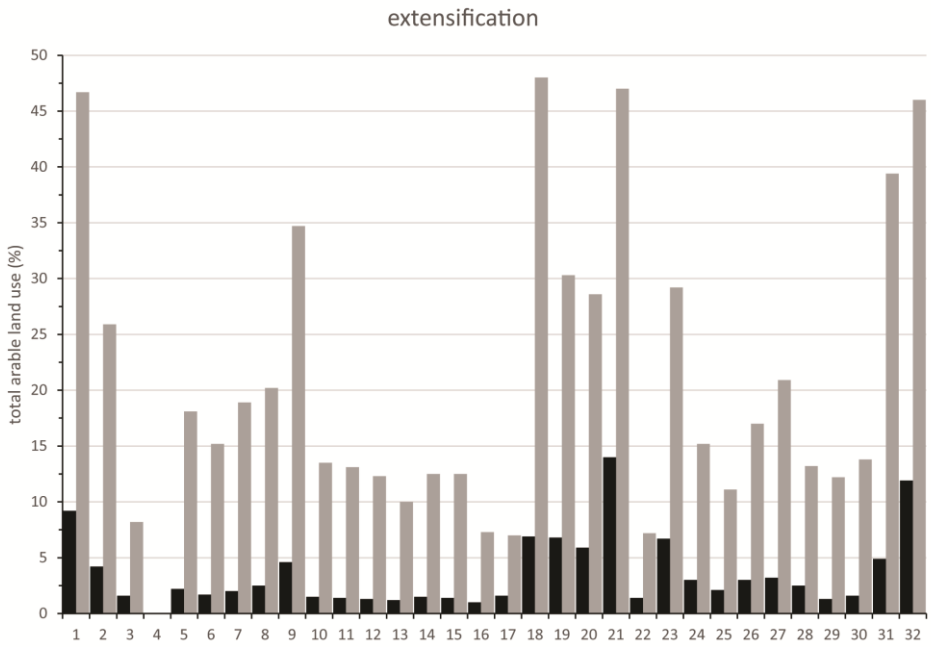
allocation over land units:
demand not met in all scenarios

OUTCOMES (PLUS)



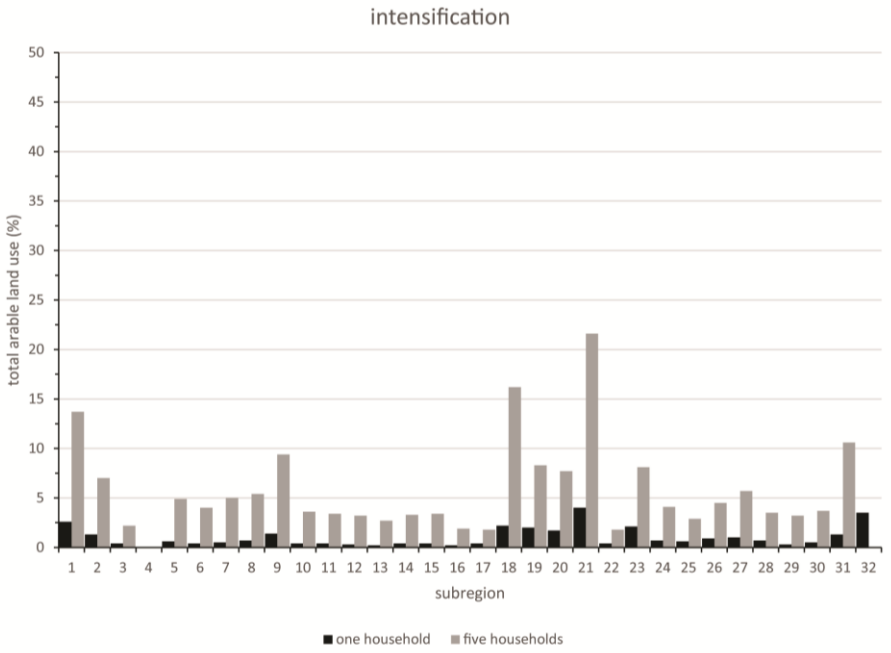
unproductive areas used
in some scenarios (competition for land)

OUTCOMES (ROMFARMS)

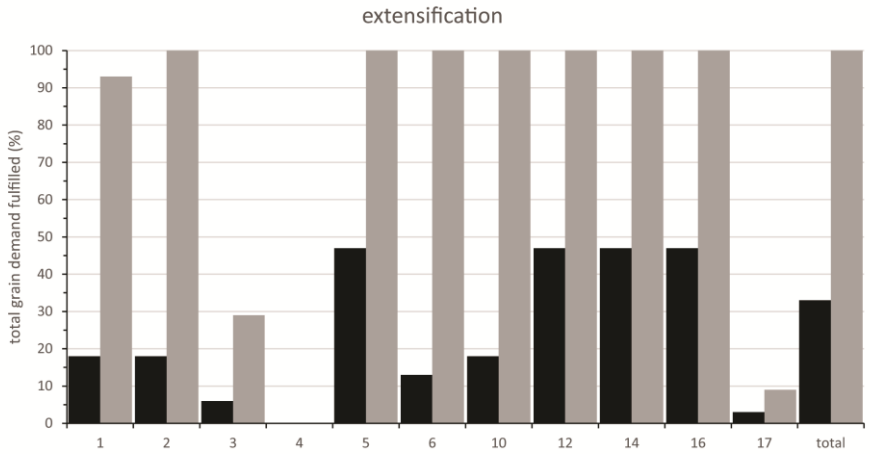


two scenarios: extensification and intensification

workforce not sufficient to take all available land into production

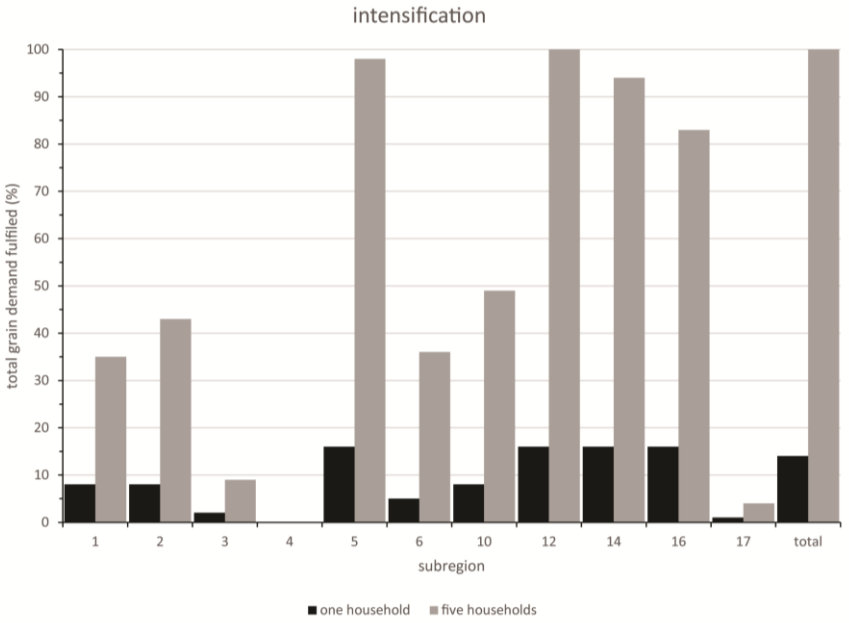


OUTCOMES (ROMFARMS)



local demand only fulfilled when sufficient workforce is available

regional redistribution likely



VALIDATION

- outcomes restricted to yields (calories) and area used (hectares)
  - PLUS also predicts the spatial allocation of land use categories
- internal validation
  - what model parameters are most influential?
  - equifinality?
- external validation
  - plausibility of outcomes
    - where is land use predicted?
    - do demographic estimates match the evidence?

COMPATIBILITY

- ABM simulation dominant in archaeology
  - geographical scale of most interest to archaeologists, local and (micro-)regional
  - lack of spatial simulation models at the intermediate level (macro-regional / national)
    - added value of the PLUS

- upscaling ROMFARMS to the PLUS is easier than the other way around
  - detailed, exploratory approach of ROMFARMS useful to run more scenarios in the PLUS
  - but, ROMFARMS could benefit from advanced spatial allocation procedures

- full integration would lead to computational 'overkill'
  - however, tools for transferring approaches and principles between the models are currently lacking
    - NAS^{2}A project

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WANT TO READ MORE?

https://doi.org/10.3390/heritage4030118