**Appendix C: Land-use demand**

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The demand for specific types of land use was simulated based on quantitative palaeodemographic data (see Appendix A) and spatial ‘rules’ defined by De Kleijn et al. (accepted).

**Demands for food producing land**

Table C.1 | *Overview of the assumptions used to calculate the land-use demands of rural settlements in AD 40, AD 70, and AD 140 based on Van Dinter et al. (2014). Since the new PLUS covers the complete first millennium, settlement sizes (i.e. population numbers) were derived using the approach outlined in Appendix A and adapted per ABR subperiod. We assume that kCal requirements and production remained stable during the investigated periods. See De Kleijn et al,* (*accepted*) f*or a more detailed description of the manner in which these data were converted in the Past Land-Use Scanner (PLUS)*

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| **Demand for food (general)** |
|   | Settlement sizes (see: palaeodemographic reconstructions; Appendix A) |
|   | An adult person would on average need 2,200 kCal per day  |
|   | 67.5% of the food is acquired from arable farming (i.e. cereals) |
|   | 22.5% of the food is acquired from animal meat |
|   | 10% of the food is derived from other plant-based or animal products, which are on such a small scale that they don’t need extra land. These have therefore been left out of the calculations. |
|   |   |
| **Arable farming (cereals)** |
|   | One kg of cereals produces 3,100 kCal  |
|   | One ha produces 1,000 kg per year of which 800 kg can be consumed. The other 200 kg are needed for the next sowing season. |
|   | Half of the required kCal per year will be produced as surplus to survive bad years |
|   | After a year of arable farming, the land will be fallow |
| **Calculation for the demand of arable farming per person in rural settlement or large settlement** |
|   | (67.5 % (percentage of diet) x 2,200 kCal (daily need per person) x 365 (number of days per year)) / (800 kg (yearly weight of cereals) x 3,100 kCal (amount of kCal per kilo cereals)) x 1.5 (surplus production) x 2 (to take fallow lands into account) = **0.66 ha of arable farming needed per person** |
|   |   |
| **Pasture and Meadow (for meat)** |
|   | Every settlement had a herd of approximately 50 animals (cows) which could produce 3,800,000 kCal of meat per year (which they did not have to use) |
|   | Every heard needs 16 ha as pasture lands and 10.1 ha meadows. |
|   | In periods that lands for arable farming are fallow, these are used as pasture |
| **Calculation for the demand of pasture per rural settlement** |
|   | (22.5 % (percentage of diet) x 2,200 kCal (daily need per person) x 9.75 (number of persons per settlement) x 365 (number of days per year)) = 1,761,581 kCal |
|   |  1,761,581 kCal (required production from a herd) / 3,800,000 kCal (maximum production meat of a herd of 50 animals) = 46% of the meat had been used |
|   | 16 (ha needed for pasture for a herd of 50 cows)  **/9.75 – arable farming =** **approximately 0.97 pasture per person in rural settlement**  |
|   | **10.1 ha meadow needed per settlement / 9.75 = 1.04 ha meadow per person in rural settlement**  |

Table C.2 | *Overview of the assumptions used to calculate land-use demands by military and related settlements in AD 40, AD 70, and AD 140 based on Van Dinter et al. (2014).*

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| **Demand for land** |
|   | Roman fortress size were derived from the palaeodemographic reconstructions (Appendix A) |
|   | An average soldier needs 3,000 kCal per day, a *vicus* inhabitant 2,200 |
|   | A soldier´s diet had the same ratio as a normal person: i.e. 67.5% cereals, 22.5% meat and 10% other resources that do not need significant land |
|  | For *vici* size see palaeodemographic reconstructions (Appendix A) |
|  | 50% of the cereal was obtained locally, the rest was imported |
|  | After AD 70 resources for the Roman army were obtained only south of the border  |
|  | Arable farming for a soldier (67.5 % (percentage of diet) x 2,700 kCal (daily need per person) x 365 (number of days per year)) / (800 kg (yearly weight of cereals) x 3,100 kCal (amount of kCal per kilo cereals)) x 1.5 (surplus production) x 2 (to take fallow lands into account) = **0.89 ha of arable farming needed per solidier** |

Table C.3 | *Overview of the assumptions used to calculate land-use demands of rural-settlement inhabitants, soldiers, and large-settlement inhabitant, based on Van Dinter et al. (2014).*

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| --- | --- | --- |
| **Land-use type** | **Needed ha per person** | **Comments** |
| **Rural settlements** |
| Arable farming  | 0.70 |   |
| Pasture | 0.97 |   |
| Meadow | 1.04 |   |
| **Soldier** |
| Arable farming | 0.89 |   |
| Pasture | 0.74 | For soldiers we assume that the meat production was more efficient: 22.7 herd (=258.8 ha) was needed per 350 persons. Whereas farms have one heard per farm, produced extra surplus |
| Meadow | 0.65 | For soldiers we assume that the meat production was more efficient: 22.7 herd (=229.2 ha ) was needed per 350 persons. Whereas farms have one heard per farm, produced extra surplus. |
| **Large settlements** |
| Arable farming | 0.70 |   |
| Pasture | 0.56 | These figures assume that herds for large settlements are as efficient as for military |
| Meadow | 0.49 | These figures assume that herds for large settlements are as efficient as for military |

Table C.4 | *Demand for land use per modelled scenario.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Rural settlements | Military sites and large settlements |  | Demand for land |  |
|  ABR sub-period | **#** | **N of houses per rural settle-ment** | **N of people per house** | **N of rural settle-ments** | **N soldiers (2700 KCal)** | **N vici people (2030 kCal)** | **N urban people (2030 kCal)** | **Total n of people** | **Arable farming: self-sufficient** | **Arable farming: surplus**  | **Pasture (self-sufficient and surplus)** | **Meadow (self-sufficient and surplus)** | **Unused\_****land** |
| Hypothesis 1: Self-sufficiency |
| ERP | 1 | 1.5 | 6.5 | 1234 | 8900 | 14900 | 0 | 35832 | 8091 | 17978 | 26521 | 25631 | -78220 |
| MRP | 2 | 3 | 6.5 | 1619 | 5900 | 5900 | 9375 | 52746 | 21231 | 15547 | 43435 | 44091 | -124304 |
| LRP | 3 | 1.5 | 6.5 | 664 | 0 | 0 | 0 | 6474 | 4354 | 0 | 6270 | 6706 | -17330 |
| EMPA | 4 | 3 | 6.5 | 306 | 0 | 0 | 0 | 5967 | 4013 | 0 | 5779 | 6181 | -15973 |
| EMPB | 5 | 3 | 6.5 | 856 | 0 | 0 | 1000 | 17692 | 11225 | 672 | 16723 | 17784 | -46404 |
| EMPC | 6 | 3 | 6.5 | 1636 | 0 | 0 | 11500 | 43402 | 21454 | 7734 | 37294 | 38711 | -105193 |
| EMPD | 7 | 5 | 6.5 | 1422 | 0 | 0 | 2600 | 48815 | 31079 | 1748 | 46207 | 49155 | -128189 |
| ERP | 8 | 3 | 6.5 | 1234 | 8900 | 14900 | 0 | 47863 | 16182 | 17978 | 38174 | 38094 | -110427 |
| MRP | 9 | 6 | 6.5 | 1619 | 5900 | 5900 | 9375 | 84316 | 42462 | 15547 | 74012 | 76795 | -208816 |
| LRP | 10 | 3 | 6.5 | 664 | 0 | 0 | 0 | 12948 | 8707 | 0 | 12541 | 19241 | -40489 |
| EMPA | 11 | 6 | 6.5 | 306 | 0 | 0 | 0 | 11934 | 8025 | 0 | 11559 | 12362 | -31946 |
| EMPB | 12 | 6 | 6.5 | 856 | 0 | 0 | 1000 | 34384 | 22450 | 672 | 32890 | 35075 | -91088 |
| EMPC | 13 | 6 | 6.5 | 1636 | 0 | 0 | 11500 | 75304 | 42907 | 7734 | 68192 | 71759 | -190592 |
| EMPD | 14 | 10 | 6.5 | 1422 | 0 | 0 | 2600 | 95030 | 62158 | 1748 | 90968 | 97029 | -251903 |
| Hypothesis 2: Roman military presence |
| ERP | 15 | 3 | 6.5 | 1234 | 8900 | 14900 | 0 | 47863 | 16182 | 8989 | 30740 | 38094 | -94004 |
| MRP | 16 | 6 | 6.5 | 1619 | 5900 | 5900 | 9375 | 84316 | 42462 | 7774 | 67583 | 71101 | -188920 |
| ERP | 17 | 1.5 | 6.5 | 1234 | 8900 | 14900 | 0 | 35832 | 8091 | 0 | 11653 | 12463 | -32207 |
| MRP | 18 | 3 | 6.5 | 1619 | 5900 | 5900 | 9375 | 52746 | 21231 | 0 | 30577 | 32704 | -84512 |
| Hypothesis 3: Dorestad |
| EMPC | 19 | 6 | 6.5 | 1636 | 0 | 0 | 6500 | 70304 | 42907 | 4371 | 65412 | 69296 | -181986 |
| EMPC | 20 | 3 | 6.5 | 1636 | 0 | 0 | 1500 | 33402 | 21454 | 1009 | 31733 | 33786 | -87981 |