

Granaries and the Grain Supply of Roman Frontier Forts: Case Studies in Local Grain Production from Haurra (Jordan), Vindolanda (Britain), and Vindonissa (Switzerland)

by

Kelsey Marie Koon
B.A., Queen's University, 2010

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

MASTER OF ARTS

in the Department of Greek and Roman Studies

© Kelsey Marie Koon, University of Victoria 2012

All rights reserved. This thesis may not be reproduced in whole or in part, by photocopy or other means, without the permission of the author.

Supervisory Committee

Granaries and the Grain Supply of Roman Frontier Forts: Case Studies in Local Grain Production from Haurra (Jordan), Vindolanda (Britain), and Vindonissa (Switzerland)

by

Kelsey Marie Koon
B.A., Queen's University, 2010

Supervisory Committee

Dr. John P. Oleson (Department of Greek and Roman Studies)
Supervisor

Dr. J. Geoffrey Kron (Department of Greek and Roman Studies)
Departmental Member

Abstract

Supervisory Committee

Dr. John P. Oleson, Department of Greek and Roman Studies

Supervisor

Dr. J. Geoffrey Kron, Department of Greek and Roman Studies

Departmental Member

This thesis addresses the question of whether Roman military garrisons on the frontiers of the Empire could sustain their annual supplies of grain from the local countryside; and if they could, to what extent. The paper examines first the general diet of a Roman soldier and the administrative and logistical system by which the military was supplied with its required foodstuffs. Three case studies of specific forts: Haurra in present-day Jordan, Vindolanda in present-day Britain, and Vindonissa in present-day Switzerland, based on the surviving granary structures of the forts and on the theoretical grain yields of the area, show that it was possible for these forts to supply themselves with their annual requirements of grain from the local area, without recourse to costly importation.

Table of Contents

Supervisory Committee	ii
Abstract	iii
Table of Contents	iv
List of Tables	v
Acknowledgments.....	vi
Introduction.....	1
Chapter One: The Military Diet.....	10
Men	10
Animals	16
Water.....	21
Chapter Two: The Military Grain Supply.....	25
Production: Growth, Yield, and Harvest.....	25
Provisioning: Officials and Infrastructure	34
Distribution: Transport and Storage.....	50
Allocation: A Soldier's Rations	59
Chapter Three: The Fort at Haurra (Humayma)	66
Granary Structure.....	67
Local Grain Production.....	74
External Sources of Food.....	85
Chapter Four: The Fort at Vindolanda (Chesterholm).....	90
Granary Structure.....	93
Local Grain Production.....	97
External Sources of Grain.....	106
Chapter Five: The Fort at Vindonissa (Windisch).....	111
Granary Structure.....	112
Local Grain Production.....	118
External Sources of Food.....	125
Conclusion	129
Bibliography	135
Appendix A: Total Annual Requirements of Grain for Haurra, Vindolanda, and Vindonissa.....	144
Appendix B: Transportation Costs to Haurra, Vindolanda, and Vindonissa	147
Appendix C: Total Arable Land Requirements for Haurra, Vindolanda, and Vindonissa	148

List of Tables

Table 1: Monthly Grain Rations According to Polybius	34
Table 2: Monthly Grain Rations in Kilograms	35
Table 3: Total Number of Auxiliary Units	38
Table 4: Total Numbers of Cavalry Horses	39
Table 5: Total Numbers of Military Mules.....	41
Table 6: Annual Requirements of Grain for Haurra (Metric Tons).....	144
Table 7: Annual Grain Requirements for Vindolanda (Metric Tons).....	145
Table 8: Annual Requirements of Grain for Vindonissa (Metric Tons).....	146
Table 9: Summary of Minimum and Maximum Transportation Costs.....	147

Acknowledgments

I would like to gratefully acknowledge my supervisor, Dr. John Oleson, for his guidance and advice in the preparation of this thesis. His academic expertise, patience, and assistance have been invaluable. I would also like to thank Dr. Geoffrey Kron for his contributions, and my external examiner, Dr. Marcus Milwright.

I am grateful to the staff of the McPherson Library for providing the research materials upon which I relied for the preparation of this thesis, and for their efforts in locating the ones which were not immediately on hand. I also wish to thank Sonja Bermingham for all her help with administrative matters during the course of my degree.

I would also like to acknowledge the support of my fellow graduate students both past and present, whose friendship and camaraderie have consistently brightened my days in the graduate student office.

I am also grateful for the inspirational example of Mr. Chester Tylinski of Northside College Preparatory High School in Chicago, for his passionate commitment to teaching and for the engaging and supportive learning community he crafted for his students; both of which have motivated me to pursue my own career in academics.

Most importantly, I am indebted to my parents, Rob and Jean Marie Koon, without whose love, commitment, teaching, and encouragement this thesis would not exist.

Thank you everyone, very much.

Introduction

Sicut fieri per omnes limites salubri prospectione praecipimus, species annonarias a vicinioribus limiti provincialibus ordinabis ad castra conferri.

“Just as we, with beneficial foresight, have commanded to be done over all the frontiers, you shall arrange that the goods of the food supply be brought to the camps by the local people who are nearest to the border.”

Cod. The. 7.4.15

The above edict, issued by the emperors Valentinian and Valens c. 369 A.D., is probably the most unambiguous reference to the Roman government supplying the army's food from sources as close to the soldiers themselves as possible. The question of whether the Roman military garrisons of the frontiers could have relied upon local supplies of food, and if so, in what proportions, is a complicated one, made more so by the scarcity of direct evidence one way or the other. Studies of the imperial economy, such as those undertaken by Garnsey or Rickman,¹ tend to concentrate on supplying civilians in the central Empire, or the city of Rome itself, rather than the peripheral areas where the majority of the army was stationed. Nevertheless, when attempting to understand the relationships that existed between the Roman garrisons and the local civilian populations of the areas in which they were installed, the issue of local production of staple foods must be investigated.

One of the primary points of contact between the Roman military and the civilian populations must have been regarding food, whether it was exacted as taxes or purchased by the soldiers themselves, and the development of this economic relationship would have opened the door to other forms of interaction. The existence of such a military food economy on the frontier is still contested in scholarship: Whittaker, for example, argues that in the agriculturally marginal regions of the empire, specifically on Hadrian's Wall in

¹ Garnsey (1988) & Rickman (1980)

northern Britain, the installation of an army garrison would have been too much of a strain on the already-struggling agricultural community for the garrison to rely on local supplies in any large amounts.² It is evident, however, that the garrisoning policy of the Roman military organized its outposts so that no one vicinity was taxed too harshly by the army's demands.³ Manning argues that cereal agriculture in the marginal areas of Britain both predated the Roman occupation and could have theoretically been more productive than previously believed.⁴ Cereal production in the garrisoned parts of Wales and northern Britain during the Roman period, in fact, appears to have been tied to the military occupation: production peaks during the late first century A.D., when the garrisons were operational, and drops off again as the garrisons were removed in the second century A.D.⁵ Though the hard evidence itself is scarce, this paper presents detailed case studies of three particular forts in an attempt to synthesize the facts that do exist into a model of sustainable local production of grain, the most important staple food eaten by the Roman military. The sources of other foodstuffs are also mentioned. The results of these case studies show that it was possible for the garrisons at these sites to draw on significant local resources of both arable land and grain production, which could supply both their annual needs and the needs of the local civilians.

The viability and sustainability of a Roman frontier garrison was directly dependent on how easily it could be supplied with the necessities of food, fodder, and water. An army on active campaign, on the move from place to place and therefore with a wider range of locations to draw upon, could conceivably depend on forage or requisition to supply its

² (2002)

³ Bishop (1999), 112

⁴ (1975b)

⁵ Manning (1975b), 115

needs. An army in garrison had no such luxury, since it was expected to remain in one area and could not move on to forage for or demand more supplies. Feeding a marching army was a short-term problem, feeding a garrison was a long-term one. It was both a tactical and logistical necessity, therefore, that Roman garrisons were established in such a way that they minimized both stress on the local economy and the distance supplies were required to travel in order to reach them.⁶

Archaeological evidence from Roman military sites in northern and central Europe suggests that while the soldiers did import foods, these were more often small-scale imports of luxury items, such as fruits, herbs like dill and coriander, and condiments.⁷ Evidence from amphorae found at military sites indicates that the foods which the soldiers imported in bulk were more often wine, olive oil, and the ever-popular *garum*, Mediterranean staples that could not be produced in areas of the Empire such as Britain and Germany.⁸ Staple foods that were consumed in bulk, such as meat and grain, were more often obtained from local resources. Arguably, the army began taking advantage of local resources of food as soon as it established itself in a new area. Cattle bones and grain assemblages from Roman military outposts in Britain, dating to immediately after the conquest in 43 A.D., show large proportions of local cattle breeds and of barley, suggesting that the soldiers were taking advantage of local production of beef and grain, and depending on what was immediately available from the surrounding area.⁹ Whittaker suggests that the installation of a garrison would have initially posed difficulties for the local population in terms of raising the necessary levels of production, subsequently

⁶ Bishop (1999), 12

⁷ Stallibrass & Thomas (2008), 9

⁸ Cherry (2007), 731

⁹ Stallibrass & Thomas (2008), 9

mandating that the garrison rely on imports.¹⁰ Perhaps this was the case for the first few years, but such short-term impacts are difficult to detect archaeologically, and it seems that they were either not very serious or entirely nonexistent.¹¹

The soldiers of the Roman army had a demonstrably varied and nutritious diet, and within the vast variety of foods available to soldiers across the frontiers of the Empire, the one constant was grain. Meat consumption might lend itself more suitably to an archaeological study, as animal remains are easier to identify in the archaeological record than plant remains, but meat consumption could vary based on location. The soldiers at Bearsden in Scotland, for example, evidently consumed very little meat.¹² Grain, provided as part of a soldier's government-issued rations, is the only component of the military diet for which an amount is specifically cited, and based on this it seems that a soldier's grain ration composed approximately 60-75% of his daily food supply. Adequate supplies of such an essential foodstuff could hardly have been left to chance if the military garrisons of the frontiers were to remain viable and active. Long-distance transport of grain, however, is complicated by the conditions of the grain itself: it must be kept dry, cool, and free of vermin infestation throughout the trip, or it will be inedible when it finally reaches its destination. The closer the origin of the grain to its eventual destination, therefore, the less concern there would be about spoilage or loss in transit. Cereal agriculture in Britain and northern Europe, for example, predates the Roman occupation, and at least one variety of grain known to the ancient Romans could survive in all the environments that the Roman garrisons encountered.

¹⁰ (2002), 225

¹¹ Stallibrass & Thomas (2008), 10

¹² Breeze (1993), 269

The supply of grain to the army and the supply for the civilian *frumentationes* at Rome represented the two major expenditures of grain by the Roman state.¹³ Supplies of grain would have to be organized not only for the soldiers themselves, but also for the animals, especially warhorses, for which grain ration amounts are also quoted in the ancient sources and which would need their full grain ration if they were on active duty. The avenues of this supply therefore must have been organized in order to keep supplementary costs, such as transport, manageable. It is likely that some sort of centralized military supply system existed under the jurisdiction of the Roman government, though the ultimate success of this supply system would depend on the reports from the unit level, which were collated into a uniform picture of supply needs. Nominally, these supply needs were overseen by the emperor and his cabinet officials, but given the complexity of the system and the distances involved in communicating supply needs to the government at Rome, a certain amount of decentralization and flexibility must have existed in the supply system if the needs of the soldiers on the ground were to be met expediently. Provisions were made for the unit commanders and soldiers on the ground, those immediately aware of what was needed and in what amounts, to supply themselves. Soldiers were permitted to requisition or purchase goods from civilians on both large and small scales, notably by the process of *frumentum emptum*, or the requisition of grain at a fixed price.¹⁴ Continuous requisition of goods from the local populace, however, carried the potential for abuse, as attested in the records of numerous native rebellions against Roman occupation,¹⁵ and avoiding this type of abuse would necessitate a more egalitarian method of supply and exchange, by which

¹³ Roth (1999), 43

¹⁴ Breeze (1993), 277

¹⁵ Monfort (2002), 72

both the soldiers and the civilians could benefit economically. Epigraphical evidence attest to the existence of areas of land around military establishments that were set aside specifically for the needs of the garrison. These lands could cover large areas, encompassing a wide variety of agricultural, pastoral, and material resources, and their aim must have been to provide the garrison with the resources it would need to sustain itself.¹⁶ Some of these lands may have been leased to local civilians by the units, under the condition that they provide a portion of their produce to the army garrison, either as rent on their lands or as part of their yearly tax revenue.¹⁷

Even in areas where extended supply lines to frontier garrisons were possible, they would prove an economic and tactical liability. Bulk shipments of food, especially grain, had to be shipped by water wherever possible, given that the cost of overland transport, at least according to the transport tariffs cited in Diocletian's *Edict on Maximum Prices*, would quickly become unsustainable for such large quantities of cargo. Obviously, shipping by water was limited to areas with access either to the sea or to navigable rivers: the forts of the Eastern desert were immediately precluded from water-borne shipping, as were the majority of the forts on Hadrian's Wall (although they were often near rivers, those rivers were not well-suited to long-distance transport¹⁸). On top of the monetary cost, bulk transport was also subject to time constraints. Grain was usually only available on a seasonal basis; it took time to grow and could be harvested only perhaps twice a year. Local production of grain, however, would reduce the impact of time on the procurement of sufficient supplies: the harvest could be brought straight up from the fields, free from the slow pace and uncertain timetable of transportation.

¹⁶ Manning (1975b), 115

¹⁷ Manning (1975b), 116

¹⁸ Manning (1975b), 114

In every instance: time, money, logistical simplicity, and sustainability, it makes the most sense for a frontier army garrison to obtain as much of their food from as close to the fort as possible. The object of the case studies in this paper is to investigate to what extent this could be done, at least at the three forts covered. Based on the evidence which does exist—the structure of the fort’s granary, the yearly rations issued to Roman soldiers, and the projected yields of cereal farming in the areas where these forts were located—the three case studies presented here attempt to construct a model that reveals both the amounts of grain that a particular garrison would require and the necessary areas of land which would produce that amount. Other studies have addressed this by calculating the grain requirements and necessary land areas of the army of Britain or the army of the Rhine frontier.¹⁹ This study, however, will focus on only three specific garrisons, and attempt to provide a more specialized view of the factors affecting a garrison’s ability to supply itself with grain. From the results of the investigation, it is possible to demonstrate that these three garrisons could conceivably obtain all of their yearly grain requirements from local sources near the fort, and that doing so would drastically reduce the supplementary costs of importing the grain to the site from further afield.

Three frontier forts in particular were chosen for case studies of how extensively the resident garrison might rely on local production for their annual grain requirements: Haurra in Jordan (modern Humayma), Vindolanda in northern Britain (modern Chesterholm), and Vindonissa in Switzerland (modern Windisch). These forts all have substantial excavated granary buildings, or *horrea*, shaped by and used for the storage of the army’s grain rations. *Horrea* are among the most substantial buildings found in

¹⁹Cherry (2007), 728

Roman frontier forts, both legionary and auxiliary, and because of their recognizable profile and their ubiquity in military installations, the information that can be gleaned from these buildings is important to the study of the military grain supply. Studies of the dimensions of known granaries, such as those carried out by Gentry and Richardson, show that despite the uncertainty about the internal arrangements of these structures and the method of grain storage within them, military granaries could usually have held enough grain to supply their respective garrisons for a year, which would be expected given the seasonal availability of grain and the need to stockpile it for distribution after the harvest.²⁰

The three forts in this paper also represent a sampling of the varied garrisoning, climatic, and agricultural conditions on the frontiers of the Roman Empire. Hauarra, in the Jordanian desert, was staffed by a legionary detachment, Vindolanda was an auxiliary fort in the highlands of northern Britain, and Vindonissa was a legionary base on the river frontier of Germany. All these forts would have had different requirements for food and fodder, and would have needed to fill these requirements in different ways according to their location. Hauarra, cut off from water transportation, would have faced high overland transportation costs if it were to import its grain, and therefore had more motivation to encourage and rely on local supply. Vindolanda, at least in the early phases of its existence predating the construction of Hadrian's Wall, was an important frontier station charged with patrolling and protecting transport along the Stanegate, and so would need to remain viable and active by taking control of the sustainable resources in the vicinity. Vindonissa, as a major legionary base, would have required substantially larger amounts of grain to fill its yearly needs; and though transport along the Rhine river was possible at

²⁰ See Gentry (1976) and Richardson (2004).

this site, the necessary volumes of grain and the time and effort required to produce and transport them would have encouraged the garrison to obtain as much of its supply as possible from near the fort. The continuation of pre-Roman cereal regimes at all three of these sites; barley at Haurra, and both barley and spelt at Vindolanda and Vindonissa, suggests that the Romans were making use of agricultural paradigms which already existed before the garrisons arrived. At each location, there were sufficient reserves of land and grain to sustain the annual requirements of both the garrison and the local civilians, and the most logistically and fiscally prudent option would be to take advantage of these resources.

Chapter One: The Military Diet

Men

When Tacitus relates the grievances of the mutinous legionaries of 14 A.D., the perennial military complaints of poor, insufficient, or otherwise unsatisfactory food are not among them.¹ All evidence indicates that the diet of Roman soldiers was of exceptional quality and quantity, and probably either similar to or even more varied and nutritious than the diet of many civilians. Scurvy (common in cases of nutritionally poor diets, namely those deficient in Vitamin C) appears only once in reference to the military, occurring only under the most extreme circumstances, and the military doctors both recognized and had a cure for it.² Plutarch mentions that lentils and salt were distributed to the soldiers at Carrhae as part of their rations,³ and Appian notes that wine, olive oil, and salt were necessary for the health of the soldiers; as eating only bread and boiled, unsalted meat upset their digestion.⁴ A fragmentary papyrus from 199 A.D. lists a range of foods provided by the local populace for the soldiers in Egypt: wheat, lentils, ham, cattle, calves, goats and pigs, as well as wine to drink and radish oil for cooking.⁵ A collection of *ostraka* found at Wadi Fawakir in Egypt are mostly letters from soldiers to their families or friends, often requesting or confirming their receipt of food (receiving special food from home was a common way for soldiers to supplement their diet). These letters mention various types of grains, salad greens, preserved fish, onions and radishes, cabbage, wild fowl and game, grapes, coconuts, condiments and seasonings, salt, beans

¹ *Ann.* 1.35

² Davies (1971), 137

³ *Crass.* 19.5, an omen of their forthcoming destruction, as these were also foods associated with funerals.

⁴ *Hisp.* 9.54

⁵ *PSI* 683

and other vegetables, baked bread, and cheese as well as wine and cooking oil. It is clear that Roman soldiers had a wide variety of foodstuffs at their disposal, besides what was provided by the government for their rations.

Previous scholarship held that meat was only a food of last resort and not well-liked by the men. This belief may have arisen from a misinterpretation of certain passages in the ancient written sources,⁶ or from the perception in the written sources of sparing meat consumption as fitting for a simple military diet, or from complaints by the soldiers when their diet was only or primarily meat, rather than the variety to which they were accustomed.⁷ Davies, in his 1971 article on the Roman military diet,⁸ soundly overturns this outdated belief, showing that Roman soldiers routinely ate meat as part of their daily meals. A soldier's kit included a roasting spit and a boiling pot for cooking meat, and animal bones excavated from military sites show that beef and pork were popular. Meat had the advantage of being readily available wherever the soldiers happened to be; animals could be raised or found in the surrounding countryside or transported on the hoof, and meat could be shipped as preserved joints.⁹ Meat was also a relatively compact source of calories compared to grain; a Roman soldier's daily meat ration contained almost twice the calories-per-gram of his grain ration, as well as being a good source of necessary proteins and fats.¹⁰ Polybius mentions that northern Italy supplied the majority of pork for soldiers serving overseas,¹¹ and numerous accounts of Roman military campaigns mention campaigning armies driving their cattle along with them or capturing

⁶ Groenman-van Waateringe (1997), 261

⁷ Tac. *Ann.* 14.24

⁸ See Appendix, Davies (1971), 138

⁹ Groenman-van Waateringe (1997), 261

¹⁰ See Roth (1999), 43

¹¹ 2.15.2-3

it from their enemies.¹² These sources seem to suggest that cattle were transported on the hoof, whereas pigs were slaughtered and then transported as either salted pork or preserved hams, at least during active campaigns. Soldiers in garrison could also supplement their meat intake with wild game, and hunting seems to have been both a source of food and a sport to occupy soldiers' spare time.¹³ Venison, boar, and hare are most commonly represented, although occasionally fox, wolf, and elk were also taken. Vegetius also recommends recruiting butchers and hunters into the ranks for their skills.¹⁴ The presence of complete or near-complete skeletons of animals at several military sites suggests the practice of live animal husbandry by some units, and tool marks on animal bones show on-site butchering on animals. Live animals would also provide milk, and in fact cheese-presses found at some sites show that the soldiers sometimes made their own cheese.¹⁵ The soldiers would also eat the meat from sacrificial animals; the *Feriale Duranum*, the list of military festivals celebrated by all Roman soldiers, lists at least 23 oxen, 12 cows, and 7 bulls as required for annual sacrifices.¹⁶ Poultry and fowl, both domestic and wild (and their eggs), are also evident in the archaeological record as bones from adult animals and eggshells. Vegetius advocates keeping chickens as meat during a siege, since they are cheap to maintain, a quality which makes them useful for the day-to-day diet as well.¹⁷ According to Pliny, auxiliary troops in Germany were sometimes sent out by their commanders to capture white geese for their feathers (which fetched a good

¹² Roth (1999), 28

¹³ See an inscription dedicated by Minicianus of the *ala Sebosiana* for his capture of "a boar of outstanding fineness, which many of his predecessors had been unable to catch", *ILS* 3562

¹⁴ 1.7, specifically the "hunters of deer and of boars"

¹⁵ Davies (1971), 128

¹⁶ *P. Dura*. 54. These sacrifices would have to be performed by every unit, so the number of sacrificial animals required for these festivals must have been quite large.

¹⁷ He also mentions that chicken is beneficial for the sick (*Mil.* 3.2), and excavation in the military hospital of Neuss yielded eggs as part of the diet fed to ailing soldiers.

price), and these birds were likely also eaten by the soldiers.¹⁸ Fish and shellfish were also popular meat products. Numerous forts in Britain have produced evidence of oysters (both natural and farmed), mussels and edible snails which may have been introduced to Britain by Roman garrisons. Shellfish were often imported far inland to military sites, for example, to Hadrian's Wall from southern England, or to Switzerland from Portugal.¹⁹ Fish could be dried or salted the same way that meat could, and fishing hooks found at forts near rivers suggest the soldiers also caught fresh fish. The remains of fish are somewhat rarer to find than those of shellfish, given the delicate nature of fish bones, and the fact that due to their fragility they are often missed in archaeological excavations.

The military diet also encompassed fruits and vegetables. Fruit, *poma pabulum*, is seldom mentioned as a component of the military diet, but it was one of the items that, according to the military oath, soldiers were allowed to carry off for themselves while on campaign. This suggests that it was an item which soldiers were expected to obtain on their own, rather than being issued it as part of their rations, and in peacetime soldiers had access to a wide variety of both cultivated and wild fruit.²⁰ Roman military sites in central Europe often had access to luxury imports like pomegranates, dates, and figs, as well as local varieties of fruit.²¹ As in the modern world, the Romans also considered fruit a health food, and Vegetius advocates gathering as much fruit as possible within the fortifications in the event of a siege.²² Common vegetables were legumes, such as lentils, beans, and peas, which also functioned as a good source of protein in the absence or

¹⁸ *HN*, 10.27.54

¹⁹ Davies (1971), 129. For importation of oysters to central Europe, see also G.E. Thüry (1990) "Römische Austerfunde in der Schweiz, im rechtsrheinischen Süddeutschland und in Österreich" pp. 285-301 in *Festschrift für Hans R. Stampfli—Beiträge zur Archäozoologie, Archäologie, Anthropologie, Geologie, und Paläontologie*. Basel: Helbing & Lichtenhahn.

²⁰ Roth (1999), 42

²¹ See Bakels & Jacomet (2003), 547. For pomegranates at Vindonissa, see Jacomet et al. (2002)

²² *Mil.* 3.3

scarcity of meat. There is also evidence of leafy vegetables such as cabbage and root vegetables such as carrots and beets at a few military sites.²³

Olive oil and wine were also components of the military diet, and the army is often credited with the northward spread of trade and cultivation of these Mediterranean commodities. Soldiers were issued olive oil and sour wine, *acetum*, as part of their rations, and amphora stamps found at military sites in Germany and Britain indicate that soldiers often imported better vintages of wine, as well as a variety of herbs and condiments (mainly honey and *muria*, a less-expensive version of the popular Roman condiment *garum*). Beer also seems to have been an especially popular drink among soldiers: an ex-military veteran of the first century A.D. became a supplier of beer to the military market in Germany.²⁴

Of all the varied foods consumed by Roman soldiers, the one constant for soldiers throughout the empire was grain. Although it must have been supplemented with other food groups to maintain the soldier's total health (grain is deficient in vitamins A, C, and D, as well as in protein), and it has been calculated that a soldier's grain ration accounted for approximately sixty to seventy-five percent of his total caloric intake.²⁵ Grain could be made into a porridge, *puls*, or more commonly ground and baked into bread. While the army at times issued baked bread or biscuit as the soldier's grain ration, this was mainly for tactical reasons. It was not always tactically expedient for the soldiers to bake their own bread due to, for example, an unavailability of firewood for cooking fires, or time constraints for a particular march. Baking bread was seen as a normal daily duty for the

²³ Davies (1971), 133

²⁴ Davies (1971), 133

²⁵ Roth (1999), 18. This may be a significant overestimate that does not account for the calories obtained from other foodstuffs such as meat and oil, for which daily consumption rates are difficult to determine.

soldiers, so it seems likely that the grain ration was issued as loose, raw grain. Herodian points out that Caracalla ground and baked his own bread to emphasize the emperor's pursuit of a simple soldierly life.²⁶ Pliny identifies this hand-ground, hand-baked bread as *panis militaris*, or "military bread",²⁷ and this type of whole-meal bread has a higher nutritional value than white bread, since it is richer in vitamins. This is a further advantage to the soldiers producing their own bread from scratch, in addition to the elimination of large and cumbersome military kitchen operations.

A soldier's daily state-issued rations seem to consist of a few staples, which could be supplemented by other foodstuffs according to their availability. According to the Egyptian *ostraka*, these rations were separated into two categories for record-keeping. The grain ration, or *frumentum*, was the primary category; and the rations of other foods, the *cibaria*, was secondary.²⁸ This shows that there was variety in the state-supplied ration, which the individual soldiers then had the opportunity to supplement. Vegetius cautions commanders always to ensure a sufficient supply of grain, vinegar, wine, and salt.²⁹ The *Historia Augusta's* biography of Hadrian refers to three staples of the camp diet: salted pork (*lardum*), cheese, (*caesum*), and a type of sour wine mixed with water (*posca*).³⁰ The omission of grain in this instance is most likely attributable to grain's obvious role as a military foodstuff. An Imperial rescript from the fourth century A.D. lists a soldier's rations as baked bread or hardtack, salted pork or mutton, wine or vinegar, oil and salt.³¹ From such sources it is possible to divide the soldier's daily rations into the following categories: grain (either raw, or as bread or hardtack), meat (typically

²⁶ 4.7.5

²⁷ *HN*. 18.12.67

²⁸ *SB* 6970

²⁹ *Mil*. 3.3

³⁰ *SHA, Hadr*. 10.2

³¹ *Cod. Theod*. 7.4.6

salted pork), vegetables (usually legumes such as lentils or beans, as these were more durable than other vegetables), cheese, salt, wine (most often vinegar or sour wine), and olive oil.³²

The diet of a Roman soldier, especially in peacetime or in garrison, when he had the time and leisure to procure his own food, was notably varied and nutritious. The state-supplied rations covered the basic necessities and soldiers could supplement these staples on their own in several ways. The diets of a garrisoned soldier and a local civilian were likely to be very similar, since the local sources of food would be available to both the soldiers and the civilians.

Animals

For a pre-industrialized army without access to motor vehicles, feeding cavalry mounts and pack animals takes on an importance nearly equal to feeding the men themselves. The *Historia Augusta* lists fodder as the most important item for an army's success, and it was certainly the largest category by volume of provisions that the army had to procure.³³ A steady supply of sufficient quantities of good fodder was crucial to the viability of the ancient army. The Roman army made use of several types of animals for fighting and for support; horses—or camels, in the Near East—for the cavalry troops, as well as ponies, donkeys, mules, and oxen for pack and draft animals. These animals all require a varied diet to make up their daily caloric needs, much the same way humans do. A balanced diet of fodder for animals typically encompasses hard fodder (usually a grain product), green fodder (hay or straw), and pasturage (grasses or other fresh greens). All equines can

³² Roth (1999), 43

³³ *Tyr. Trig.* 18.6-9

survive without hard fodder—though an equine in work must have grain to maintain full health—but not without hay or pasturage.³⁴ In the Roman world, hard fodder was commonly barley or oats. Barley appears to have been the most common grain used for horse fodder; in addition to Polybius’s cited barley rations for cavalry horses, papyrological records from Egypt and Dura Europos mention barley being procured for military horses.³⁵ In the late Empire, a similar system to the military *annona*, the *capitus*, was set up to provide animal fodder, and its allocations consisted primarily of barley.³⁶ It has also been theorized that Roman cavalry garrisons in Britain encouraged the cultivation of oats in the province to provide fodder for their horses.³⁷ Many ancient recipes for mixed feed for horses also include a proportion of beans, an excellent source of protein for both humans and animals. Towns in Campania were called upon to deliver large quantities of beans to the racing stables in Rome, suggesting that beans represented quite a large proportion of a horse’s hard fodder.³⁸ Exact weights of beans as rations for horses, however, are not mentioned in the ancient sources. The Romans used a variety of green fodder, usually hay and straw; Roman soldiers were routinely dispatched to cut hay,³⁹ and they carried sickles in their kit to cut crops when foraging. In addition to hay, green fodder included clover, vetch, grass, and alfalfa; and when necessary, the Romans used unripe grain, lentils, or the leftovers of human food, as well as the leaves and shoots of various trees.⁴⁰ Pasturage would have been eaten directly from the fields, and would consist of whatever native grasses and foliage occurred in the region. Animals could also

³⁴ Hyland (1990), 87

³⁵ *P. Oxy.* 2046, *P. Dur.* 82, 100, 101, and 129

³⁶ Dixon & Southern (1992), 217

³⁷ Dixon & Southern (1992), 211

³⁸ *Cod. Theod.* 15.10.2

³⁹ See *CIL* 8.4322 for an example of this, as well as Trajan’s Column, Scene 110 for foraging legionaries.

⁴⁰ Roth (1999), 61

be grazed in hayfields in the spring, before the hay crop was sown, and then again in late summer after the hay harvest.⁴¹

Horses, especially warhorses, while being more militarily valuable, are also the most sensitive animals with regards to diet. Roman warhorses were definitely smaller (and, perhaps, hardier and more durable because of this) than medieval or modern horses, requiring smaller quantities of feed, though they still required more care than other Roman equines. Polybius's cited barley rations for Roman cavalry horses⁴² would provide an appropriate amount of calories for these smaller horses, since ancient grains were higher in protein than modern ones.⁴³ Although no specific amounts of hay are mentioned, there are numerous military records referring to hay purchase and pay deductions toward hay.⁴⁴ Horses could also obtain a great deal of their daily nutrition from pasturage, that is, by grazing. Vegetius mentions horses being sent out to pasture while the army was encamped, and both Caesar and Ammianus Marcellinus refer to a lack of sufficient pasturage as delaying the start of a military campaign.⁴⁵ Several inscriptions (normally on the boundary stones used to partition the land) refer to *prata*, or meadowland, set aside for the military to pasture their animals, or to raise hay for fodder, though the *Codex Theodosianus* makes repeated references to abuses of grazing privileges on public and private civilian pastureland by Roman troops.⁴⁶ A horse would have to eat a much larger quantity of pasturage, however, to obtain the same amount of nutrients as it could obtain from hard and dry fodder combined. Warhorses especially

⁴¹ Hyland (1990), 91

⁴² Approximately 3 kg per day, as given in *Hist.* 6.29.12-14

⁴³ Though Hyland suggests that these rations are the bare minimum required, subsistence level only, and that horses often had more feed at their disposal. (1990), 44

⁴⁴ Hyland (1990), 90

⁴⁵ *Caes. B Gall.* 2.2, *Amm. Marc. Res Gest.* 30.3

⁴⁶ *Cod. Theod.* 7.7.1-7.7.5

needed at least some grain in their diet in order to remain healthy and fit for combat. Pasturage is also only available during the growing season, which was different for different areas of the empire. For example, pasturage in the east had mostly dried up by August, while in the wetter climates of the northwest it continued to flourish.⁴⁷ For the rest of the year the horses would have to be sustained on grain and hay.

Although baggage animals are well-represented in the archaeological, papyrological, and epigraphical records, they are notoriously absent from the works of the military writers. The military writers devote their time overwhelmingly to cavalry mounts and warhorses, although pack and draft animals no doubt outnumbered these by a huge factor and also required care and attention.⁴⁸ It is interesting that these writers, mainly concerned with tactics and logistical concerns, should leave out such a large and important component of the military system.

Donkeys require much smaller quantities of fodder than horses and indeed, can survive long periods of hunger or eating nothing at all. They also have the advantage of being able to graze on much poorer fodder such as thorns and thistles,⁴⁹ a flexibility in diet that made them useful pack animals for military operations. For example, Caesar's troops in Africa fed their donkeys on seaweed and grass when proper fodder was unavailable.⁵⁰ Donkeys, like horses, could be turned out to graze, but they were also fed hay and barley. Mules were considered more exceptional pack animals than donkeys, Trajan's Column and the Column of Marcus Aurelius have multiple renderings of military pack mules;

⁴⁷ See *Cod. Theod.* 7.4.8, decreeing that horses were not to be issued fodder before August 1st, when, presumably, pasturage was harder to come by.

⁴⁸ Hyland (1990), 87

⁴⁹ *Col. Rust.* 7.1.2

⁵⁰ *Caes. B Afr.* 24.

with panniers and packsaddles, as cartage animals, draft animals for siege engines, etc.⁵¹ Mules were also fed hay and barley, at about three-quarters the amount required by horses, but they also needed a certain amount of pasturage to keep them healthy. Mules fed only on grain become fat and high-spirited.⁵² With this in mind, they probably received less grain in their diet than horses, and could, like any equine, be turned out to graze. Donkeys and mules, however, do not do well in damp and cold conditions, such as would have existed on the northern frontiers, and in these locations they may have been replaced with draft horses and native ponies.⁵³ Caesar mentions that the Gauls had a type of sturdy draft pony.⁵⁴ British ponies were used to cart lead from the mines in northern England, and were also presumably available to the military operations of Britain.⁵⁵ It is also possible that an army in garrison, as those concerned in this paper, would require fewer pack animals for hauling gear than would an army on campaign; but the cavalry horses would need to be kept in shape with diet and exercise.⁵⁶

Oxen were used in military settings primarily for cartage, rather than being equipped with the packsaddles furnished for mules and donkeys. On the Column of Marcus Aurelius of a load of armor, weapons, and shields is carried in an oxcart. In North Africa ox carts carried grain for the *annona militaris*, there were, however, probably fewer of them than equine pack animals. Mules and horses could also be yoked to such carts, but for the heaviest loads, oxen were the preferred draft animals.⁵⁷ Oxen are more efficient than equines in terms of converting food to energy, but they also require more fodder

⁵¹ For example, Trajan's Column, Scenes 60, 63, 66, and 138.

⁵² Roth (1999), 66

⁵³ Hyland (1990), 88

⁵⁴ *B. Gall.* 4.2

⁵⁵ Hyland (1990), 88

⁵⁶ Hyland (1990), 90

⁵⁷ Raepsaet, (2008), 592

because of their size. An ox requires almost three times as much hard fodder as a horse, almost twice as much green fodder, and almost twice as much pasturage.⁵⁸

The diet of the animals used by the Roman army is almost as varied as the diet of the humans in terms of the types of grain, dry fodder and pasturage that the animals could eat. All the army's animals, cavalry and pack, could obtain a significant amount of their daily nutrition by grazing, which seems to be the primary purpose of the military *pratae*, or meadowlands, ascribed to various garrison units. Nevertheless, imperial legislation against grazing military animals on public and private land may suggest that these *pratae* were not always put to this use. In peacetime, it is possible that these animals were turned out to graze more often than not, however, a certain amount of grain and hay would be required, especially for cavalry horses, to keep the animals fit and healthy.

Water

The third pillar of the military diet, even more important than food for the men or fodder for the animals, is sufficient water for both. Each fighting man would need a minimum of two liters of drinking water per day, and an animal (horse, donkey, mule, etc.) would need between fifteen and thirty liters per day, depending on the animal, and all these requirements would be increased by hot and dry weather.⁵⁹ Insufficient water would cripple an army more quickly than lack of any other commodity—often in a matter of days—and the theme of soldiers suffering from thirst crops up in numerous military writers. Vegetius devotes an entire chapter to the provision of adequate water during a

⁵⁸ Roth (1999), 67

⁵⁹ Roth (1999), 119. See also Roth (1999), 66-67 for the daily water requirements of various animals.

siege,⁶⁰ and water was often stockpiled in forts in anticipation of sieges.⁶¹ The reservoir of the fort at Haurra, for example, could have contained a six-month supply for the garrison.⁶²

Water, along with fodder and firewood, was most often obtained locally, due to the vast quantities needed and the difficulty of transporting it long distances. A fragment of Quadrigarius (a first-century BC historian who survives primarily in quotes in Livy) advises that an army must be sure to have local supplies of fodder, firewood, and water.⁶³ Under normal conditions, naturally-occurring sources of water, such as rivers, lakes and ponds, springs, creeks, etc. would have provided sufficient amounts of water; only a very large force could not be completely supplied by these.⁶⁴ In some instances, the army could also obtain its supply from rainwater, as soldiers did in Numidia during the Jugurthine War,⁶⁵ or in North Africa in 42 A.D.,⁶⁶ or on campaign against the Marcomanni.⁶⁷ In the absence of such natural sources, the army would have to dig wells, and Appian preferred water from a fresh well to water from a stream.⁶⁸ Well-water could also backfire; wells dug by Scipio Aemilianus's men in Spain brought up bitter water.⁶⁹ For most military outposts, local supply of water was not an issue: forts in northwestern and central Europe were situated along rivers, the Rhine and Danube frontiers, for example, with plentiful access to water, though icy winter weather would have complicated the supply; see Plutarch's account of the difficulty of watering horses in an

⁶⁰ *Mil.* 4.10

⁶¹ *Caes. B. Civ.* 3.12

⁶² Eadie & Oleson (1986), 57

⁶³ *Ann.* 2.36

⁶⁴ *Tac. Ann.* 4.49, describing the predicament of Thracian rebels in 26 A.D.

⁶⁵ *Sall. Jug.* 75.7-9

⁶⁶ *Dio Cass.* 60.9.2-4

⁶⁷ *Dio Cass.* 72.10.3-4

⁶⁸ *B. Civ.* 4.14.110

⁶⁹ *App. Hisp.* 14.88

icy river.⁷⁰ In the Mediterranean summer, however, many water sources dry up in the heat, and the garrisons on the desert frontiers in the Near East and North Africa, would have had greater difficulty, given the year-round scarcity of water. Desert supplies would be an exception to the local-supply rule for water, of course; the scarcity of many necessities in the desert would demand long-distance transport of at least some of the required supplies which could be obtained on-site in other climates. For example, Gichon theorizes that the Roman force besieging Masada (approximately 8,000 men, 1,500 horses, and 4,000 pack animals) would have needed, in addition to 64,000 liters of water per day for the men and 90,000 liters of water per day for the combined total animals, a further 18,000 liters of water per day would be needed to supply the approximately 2,000 pack animals needed to cart water supplies for the army.⁷¹ Dio Cassius also mentions the difficulty that the forces in Judaea had with their water supply, saying that they employed water-carriers to transport water long distances.⁷² It is in the desert that camels, uniquely adapted to survival on the spare food and water resources in that environment, prove their worth as military animals. Forces on the desert frontiers made use of camels as military animals, attested by the presence of camelback cavalry (*equitates dromedarii*, usually auxiliary units of native camelback horsemen) in Roman military rosters in the Eastern empire,⁷³ but for the most part, camels seem to be popular as pack and working animals

⁷⁰ *Luc.* 32.1, describing the campaigns in Armenia in 69 B.C

⁷¹ Gichon (2000), 543. Gichon's daily water rations are much higher than the minimum, suggesting 8 liters per day per man and 36 liters per day per horse and 9 liters per day per pack animal, in keeping with the exertion of an active campaign and the desert conditions.

⁷² 65.4.5

⁷³ For example, the *ala I Ulpia dromedariorum miliaria* employed by Trajan in Syria, or eastern *cohortes equitatae* made up of camel riders, such as in the rosters of the *cohors XX Palmyrenorum equitata*. Dixon & Southern (1992), 32

in the desert regions of the Roman Empire.⁷⁴ Modern camels obtain most of their food intake from grazing and browsing on native vegetation, and, like donkeys, they are capable of eating rough or poor-quality fodder, and enduring long periods of hunger. Modern camels require little supplemental food, and it makes sense that ancient camels were similar in this respect.⁷⁵ In the desert winter, camels obtain much of their necessary water from grazing on local vegetation, and sometimes will not drink water at all, while in the summer, a camel can go up to two weeks without drinking.⁷⁶ Camels can also carry more than equine pack animals, meaning that fewer of them were needed to transport equivalent loads;⁷⁷ however, a camel's soft feet are not suited to mountainous or rocky terrain, and here mules were usually preferred.⁷⁸

While the soldiers and attendant animals of the Roman military enjoyed a demonstrably varied and nutritious diet, the backbone of the logistics of the military food supply was the consistent supply of grain for men and animals alike. Grain accounted for a major proportion of a soldier's daily state-furnished rations, so it makes sense to use this commodity as a marker for military supply to the frontiers, since it was a consistent concern for those in charge of the supply networks. The next chapter will examine the framework of the grain supply: its origins, the officials in charge of its procurement, and its transportation and distribution.

⁷⁴ Plin. *HN*. 8.26.67. Camels were used as military animals by various non-Roman peoples in North Africa and the Near East (such as the Achaemenid Persians) (Gauthier-Pilters & Dagg (1981) 119)

⁷⁵ Gauthier-Pilters & Dagg (1981), 33

⁷⁶ Gauthier-Pilters & Dagg (1981), 50. Camels in heavy work will need more food and water than camels at rest or camels employed as draft or pack animals.

⁷⁷ Approximately 230 kg, vs. 120 for a horse and 180 for a mule, Raepsaet (2008), 589.

⁷⁸ Roth (1999), 208

Chapter Two: The Military Grain Supply

Keeping the army of the Roman Empire in fighting shape required a massive volume of provisions, as well as a complex infrastructure to procure and account for these provisions and to transport them to where they were needed. Unfortunately, the surviving evidence of this supply system paints an incomplete picture of how it functioned. The grain supply, because of its universal importance to units stationed throughout the empire, represents the best way to study this system, which was also no doubt responsible for the provision of all military necessities. While there is continuing debate on how the system functioned, the fact remains that the army's grain had to be grown, harvested, transported, and distributed to the soldiers; and that accounts and totals would have to be kept throughout the process.

Production: Growth, Yield, and Harvest

The two mainstays of the cereal crops in the ancient Mediterranean were wheat and barley. North American corn, or maize, was unknown in Europe in antiquity; sorghum and rice were extremely rare; and oats, rye, and millet were mainly limited to areas with poor growing climates, and never took on as much importance to cereal farming as did wheat or barley.¹ Pliny goes into the greatest detail on the subject of wheat, and delineates the three most common varieties: *far*, *triticum*, and *siligo*.² Pliny's *far* is most likely emmer wheat, *triticum dicoccum*, and he also describes the variants of emmer that

¹ One theory states that Roman garrisons stationed in Britain did, however, encourage the cultivation of oats as fodder for their horses.

² *HN* 18.19.81

are grown in Greece (*zeia*), Egypt (*olyra*), as well as *arinca*, the Gallic name for *far*.³ In Mediterranean cereal cultivation dating to roughly 500 B.C., the most common crops were those in the emmer family,⁴ which, according to Pliny, could tolerate the widest variety of growing conditions, from cold and wet to hot and dry.⁵ It is unclear whether “triticum” in Pliny’s description refers to a particular species of wheat, though it may refer to *triticum durum*, or macaroni wheat, which was widely grown in Greece.⁶ *Siligo* is an ambiguous term, because it can refer both to a grade of flour fineness, and to the specific type of wheat that was most often used to make that particular grade of flour.⁷ The term most likely refers to *triticum aestivum*, or bread wheat, which produces the very fine, high-quality white baking flour used in bread making.⁸ Despite bread wheat’s limitations in the semi-arid Mediterranean climate (it is better-suited to wetter, cooler climates such as those of central Europe), it had become the most popular cultivated wheat strain by the Roman period.⁹ Pliny mentions that *siligo* is common in most countries,¹⁰ and archaeobotanical studies of Roman Imperial period sites often show a mix of bread wheat, emmer, and spelt.¹¹

Barley was arguably the cereal crop best-suited to the Mediterranean climate. It needed less rainfall, was better adapted to the nutritionally-deficient soil of the Mediterranean

³ *HN* 18.19.82

⁴ Sallares (1991), 346

⁵ *HN* 18.19.83

⁶ The Loeb edition’s translators render “triticum” as “hard wheat”, which would imply *triticum durum*, or macaroni wheat. *T. durum* does have the lowest water requirements of the naked wheats, suiting it well to semi-arid growing environments. See Sallares (1991), 313ff for a discussion on the cultivation of *T. durum* in antiquity.

⁷ Sallares (1991), 324

⁸ Sallares (1991), 325

⁹ Sallares (1991), 332

¹⁰ *HN* 18.19.81

¹¹ See below, pp. 74, 97-99, and 118

basin, and ripened earlier.¹² Barley could also yield between ten and fifty percent more loose grain than wheat; however, despite being more productive, barley was also less nutritious for humans, and more difficult to transport due to its bulk.¹³ The difficulty in removing the edible part of the barley grain from the husk (often requiring extensive roasting, which destroyed the gluten content) also discouraged its use in bread-making.¹⁴ The Greeks preferred to make barley into porridge, but more often in the Roman period it was fed to animals, except when used as military punishment rations, or as food for the poor who could not afford wheat bread. Barley also appears to have had some medicinal properties for the Romans, as barley-water (not beer, *cervesa*, but rather a sort of barley tea, *tisana*) was considered a healthy drink.¹⁵

Like any plant, wheat requires specific conditions to thrive. Too little rain, and the crop will not sprout; too much, and the seeds will drown. Most importantly in the semi-arid Mediterranean, wheat requires a bare minimum of 250 millimeters of rainfall per year to survive. Between 400-500 millimeters of rain, however, would provide a healthier and more abundant crop.¹⁶ Pliny mentions that wheat and barley are winter grains, that is, they are sown in the autumn (specifically “at the setting of the Pleiades”) and grow through the winter, when the weather patterns of the Mediterranean shift to bring rain from northern and central Europe.¹⁷ Some grains, such as millet, that require a shorter

¹² Rickman (1980a), 5

¹³ Rickman (1980a), 5

¹⁴ Rickman (1980a), 5

¹⁵ *HN*. 18.15.75

¹⁶ Depending on the species being grown; *t. durum* can survive on as little as 300 mm, while *t. aestivum* requires 500 mm or more. See Spurr (1986), 20

¹⁷ *HN*. 18.10.49

ripening time, can also be sown in the spring or the summer, but the majority of the cereal crop was typically sown before the winter rains.¹⁸

The yield, or the amount of raw grain produced, of any particular crop of wheat depends on many factors, such as soil quality, the strength of the seed, germination rate, and so on. Modern yields, augmented by industrialized farming and artificial fertilizers, can be as high as 6.25 to 7 metric tons of wheat per hectare. In comparison, yields in Iron Age Britain, between the eighth century B.C. and the early second century A.D., were approximately 1.25 to 2.25 metric tons per hectare, and these were some of the highest known until the invention of modern farming techniques.¹⁹ In antiquity, the Romans measured weight by the *modius* (roughly 9 modern kilograms), the Greeks by the *medimnus* (roughly 54 modern kg), and the Egyptians by the *artaba* (roughly 39 modern kg). Cicero says that the exceptionally fertile areas around Leontini would yield eight to ten *medimni* (approximately 48-60 *modii*, or 432-540 kg) per *iugerum* (the Roman measure of land roughly equivalent to 0.25 hectares) for every one *medimnus* (6 *modii*) of seed sown, or a ratio of roughly 1.7 to 2.1 metric tons per hectare.²⁰ Varro acknowledges that sowing rates, and subsequently yields, depend on the soil conditions, and therefore cannot be easily determined; but he nevertheless says that wheat is typically sown at a rate of five *modii* per *iugerum* (180 kg per hectare), and barley at six *modii* per *iugerum* (216 kg per hectare), which can produce yields of ten to fifteen times what was sown, (roughly 1.8 to 2.7 metric tons per hectare in the case of wheat, and 2.1 to 3.2 metric tons per hectare in the case of barley).²¹

¹⁸ Plin. *HN*. 18.10.49

¹⁹ Hyland (1990), 93

²⁰ *Verr.* 2.3.112

²¹ *Rust.* 1.44.1

Varro's account may, however, be concentrating on places with exceptional fertility, as it specifically mentions Etruria, and the figures are roughly consistent with Cicero's account of Leontini, another exceptionally fertile area for grain production. The most fertile grain belts of the Roman Empire may have had a comparable yield, and Pliny mentions that the most productive areas (Sicily, southern Spain, and Egypt) could produce yields a hundred times as large as the volume of grain that had been planted.²² Papyrological evidence from Egypt suggests that an average yield of ten times what was sown is not unreasonable, with some estates producing yields as high as fifteen times what was sown.²³ Columella disagrees, saying that at most grain yields four times what is sown, which he evidently thinks to be extremely low, though considering that the object of his argument is to encourage the cultivation of the vine (which had a higher profit margin), his figure may be either an indicator of the yield of very poor soil, or an entirely unreliable exaggeration prompted by commercial motives.²⁴ His estimate of grain yields, however, appears to be roughly consistent with tenth-century cereal farming in northern Italy.²⁵ The yields quoted by Cicero, Varro, and Pliny, however, are primarily for extremely fertile soil, so comparative evidence is needed to determine the yields of average or poor quality soil. Erdkamp argues that yields in the Mediterranean were higher than the yields of central and northwestern Europe, because the seeds of plants that ripen in the hot summer form better seed grains than those that ripen in cooler, wetter weather.²⁶ He suggests that yields in these cold, wet regions would only be about threefold or fourfold, whereas in the Mediterranean they could range from threefold for

²² *HN* 18.21.95

²³ Rathbone (2007), 704

²⁴ *Rust.* 3.3.4

²⁵ Goodchild (2007), 253

²⁶ (2005), 39

very poor quality soil (roughly 0.5 metric tons per hectare, according to Varro's figures for sowing) to twelvefold for exceptionally fertile alluvial soil (roughly 2.1 metric tons per hectare).²⁷ Studies of cereal agriculture in Tuscany during the nineteenth century suggest that yields typically averaged between six times and seven times what was sown, depending on the type of soil and the local topography.²⁸ Interestingly, yields in Medieval Sicily reflect Cicero's quoted eight-to tenfold amount, suggesting that this level of production was maintained for several centuries.²⁹ Cereal agriculture clearly had a wide range of yields, depending on location, soil conditions and type of grain sown.³⁰

Rome depended on several grain belts for a sufficient supply. These areas of the Mediterranean provided quality soil and enough rainfall for grain to be grown in bulk. This is not to say that grain was not grown in other areas, but rather that these specific regions were the major producers of the grain collected by the Roman state (either for the civilian grain doles in Rome, or for military rations). Pliny describes the most common varieties of imported wheat and their origins, which allows us to reconstruct the locations of these grain belts.³¹

Sicily, due to its fertile volcanic soil, was a major producer of grain and of vital importance to Rome. The island was a major exporter of grain from the time of the ancient Greek colonies to the sixteenth and seventeenth centuries A.D., and the plains of Catania (especially the area of Leontini) were the most productive areas, providing extremely high yields primarily of *durum*. After the death of Hiero of Syracuse and

²⁷ Erdkamp (2005), 40

²⁸ Goodchild (2007), 251

²⁹ Erdkamp (2005), 40

³⁰ The agricultural writers also advocate selecting for the largest and best-quality seeds, see Varro, *Rust.* 1.52.1, Pliny, *HN* 18.20.85, which would lead to better yields.

³¹ *HN* 18.12.66-71

Rome's annexation of Sicily at the end of the third century B.C., this grain production was reserved specifically for Rome, so much so that the island of Rhodes had to get special permission from the Roman state to draw grain from Sicily in 169 B.C.³² Fortunately, definite figures exist for the production and export of Sicilian grain (at least for the late Republican period c. 70 B.C.), in the form of Cicero's *Third Oration against Verres*. From this it seems that the annual taxation, a tenth-part of the produce of Sicily amounted to three million *modii* (27,000 metric tons.). If three million *modii* was a tenth of the production, we can assume that the total yield of the grain belts in Sicily was approximately 30 million *modii* (270,000 metric tons) per year. So even when the Roman state drew increasing amounts of grain from Sicily, up to seven million *modii* (63,000 metric tons), there was plenty left over for private commerce and for sustaining the production in the next year.³³ Sicily served as the main source of grain for Republican Rome, until it was outpaced by the greater resources of North Africa and Egypt in the Imperial period. Nevertheless, it remained a major producer; both Strabo and Pliny emphasize the importance of fine-quality Sicilian grain to Rome in the first century A.D.³⁴, as does Aelius Aristides in the second century A.D.³⁵ Sardinia, another Roman possession gained from the Punic Wars, also provided Rome with a significant supply of grain to the point that Cicero refers to Sicily, Sardinia, and Africa as "the three grain reserves of the republic".³⁶

The third of these three reserves, and in fact the most important of the three during the Imperial period, consisted of the fertile growing areas of North Africa and Egypt. In these

³² Polyb., 28.2

³³ Cic. *Dom.* 2

³⁴ Strab. 6.273, Plin. *HN.* 18.66

³⁵ *Eis Rōmēn*, 12

³⁶ "tria frumentaria subsidia rei publicae" *De Imp. Gn. Pomp.* 34

arid regions, grain cultivation was primarily undertaken in the narrow strips where precipitation was sufficient: in North Africa, Cyrene and the vicinity of Carthage, where the majority of the grain plantations were clustered (some owned by the emperor and some by independent wealthy landowners); and in Egypt, the Nile Valley and Delta.³⁷ Ancient sources hold a few testimonies of grain yields in these regions, but these accounts of productivity are not as detailed as those found in Cicero's treatment of Sicily. Josephus credits North Africa with supplying the city of Rome with two-thirds of its total annual needs, and Egypt with one-third.³⁸ Assuming that Rome's total population was approximately one million people, and assuming a yearly grain consumption of 40 *modii* (roughly 360 kg) per person per year, this gives a total requirement of 40 million *modii* per year (360,000 metric tons),³⁹ of which North Africa supplied 27 million (243,000 metric tons) and Egypt 13 million (117,000 metric tons). The *Epitome de Caesaribus*, a fourth-century A.D. unattributed work, notes that during the reign of Augustus, Rome drew 20 million *modii* (180,000 metric tons) of grain from Egypt;⁴⁰ and an edict of Justinian provides the tax in grain levied from Egypt by Constantinople as roughly 36 million *modii* (324,000 metric tons).⁴¹ If these figures represent taxation dues, (as do the numbers for Sicilian production cited by Cicero) then the total production would of course be much higher. The numbers, though they may be somewhat exaggerated, do demonstrate beyond a doubt that these two regions made up the vast majority of Mediterranean grain production.

³⁷ Rickman (1980a), 109, 114

³⁸ *B.J.* 2.383, 2.386, though he makes no mention of Sicily, which was still a major supplier of grain at this time.

³⁹ See Rickman (1980a), 10 for exact calculations.

⁴⁰ *Epit. de Caes.*, 1.6

⁴¹ *Just. Ed.* 13.8

Besides the main sources listed above, Rome also made use of subsidiary sources of grain in Gaul, Spain, and the Eastern provinces. These places did not produce grain in such great bulk as the others, but did provide good-quality secondary supplies for the western (in the case of Gaul and Spain) and eastern (from the Black Sea and the Middle East) Mediterranean markets. The fertile farming regions of southern Gaul supplied Caesar's troops during his conquests, and the produce of northern and central Gaul supplied the armies stationed along the Rhine frontier. As for Spain, both Pliny and Strabo acknowledge grain as one of its main resources,⁴² and while the eastern regions could produce enough grain to feed both the local populace and the Roman armies on campaign, it seems that only southwestern Spain, specifically the Baetis River valley, produced a significant exportable surplus.⁴³

Although Rome came to depend increasingly on overseas imports of grain as the territory and population of the empire expanded, Italy itself also produced significant crops. Even into the fourth century A.D., southern Italy (easily accessed by sea from Rome) was an important source of grain.⁴⁴ Grain farming occurred in the Po Valley and in Apulia, whose wheat Varro describes as being of particularly good quality.⁴⁵ The bulk grain-producing areas of Italy, though, seem to be the productive farming regions of Etruria, Latium, and particularly Campania, which was not subject to excessive amounts of rain that would render the land marshy and unworkable.⁴⁶ Both the coastal plains of Campania and the alluvial trough of the Val di Chiana in Etruria produced high-quality

⁴² *HN*. 18.12.66, Strab. 3.144

⁴³ Rickman (1980a), 107

⁴⁴ Cassiodorus stresses the importance of southern Italian grain to Rome's food supply, *Var.* 4.5

⁴⁵ *Rust.* 1.2.6

⁴⁶ Northern Italy and the coastal plains of Latium had become extremely marshy and waterlogged by the first century AD, as described by both Elder and Younger Plinys.

wheat crops, both *durum* and *triticum aestivum*. Pliny, in fact, disparages foreign wheat in comparison to Italian, which he says is exceptional in both weight and whiteness.⁴⁷

It is clear, then, that Rome commanded plentiful resources of grain. Productive growing areas could be found in most provinces of the empire, and the extant evidence suggests that the most productive areas furnished considerable surpluses in each growing season. Having dealt with the production of grain in general, the question is now exactly how much of that produce was requisitioned for the use of the military, and how such resources were managed by the Roman state.

Provisioning: Officials and Infrastructure

Before discussing how the army secured its grain supplies, it is useful to consider how much of those supplies it required on a regular basis. Evidence in this area is unfortunately somewhat piecemeal, so an estimate of the army's yearly grain needs will require some theoretical projections. Polybius, writing of the Republican army of the second century B.C., gives us these figures for the monthly grain rations of both Roman and allied (non-citizen) soldiers⁴⁸:

Table 1: Monthly Grain Rations According to Polybius

	<i>Wheat Ration</i>	<i>Barley Ration</i>
<i>Roman Infantryman</i>	3 <i>modii</i> (approx.)	
<i>Allied Infantryman</i>	3 <i>modii</i> (approx.)	
<i>Roman Cavalryman</i>	9 <i>modii</i>	31.5 <i>modii</i>
<i>Allied Cavalryman</i>	6 <i>modii</i> (approx.)	22.5 <i>modii</i>

⁴⁷ *HN* 18.12.63, "I shall not compare [imported varieties of wheat] at all equally with Italian wheat in whiteness or in weight, by which it is exceptionally distinguished."

⁴⁸ 6.39.12-14

In modern measures, the monthly rations break down as follows (one *modius* is roughly 9 modern kg.):⁴⁹

Table 2: Monthly Grain Rations in Kilograms

	<i>Wheat Ration</i>	<i>Barley Ration</i>
<i>Roman Infantryman</i>	27 kg	
<i>Allied Infantryman</i>	27 kg	
<i>Roman Cavalryman</i>	81 kg	283.5 kg
<i>Allied Cavalryman</i>	54 kg	202.5 kg

This comes to approximately 324 kg of wheat per man per year. The barley ration issued to the cavalymen was clearly for their horses, since barley is not issued to the infantrymen. Cavalymen were also issued extra wheat rations, presumably for grooms or attendants (of which the Roman cavalryman had two and the allied cavalryman one, based on the differences in the wheat rations). The differing amounts of barley must also correspond to a different number of mounts, or perhaps extra mounts and a pack animal (Gaius Marius furnished both a horse and a mule for inspection when he served as a cavalryman⁵⁰). There also appears to be some relation between the extra wheat rations issued to cavalymen for themselves and their grooms and the differing amounts of barley issued for their horses. If it can be assumed that each groom was responsible for one other animal in addition to the cavalryman's own horse, it is possible to infer that the Roman cavalryman commanded three animals and the allied cavalryman two. This calculation results in a monthly ration of approximately 10 *modii* (90 kg) of barley per horse, or 1,080 kg per horse per year.⁵¹ A comparison between these figures and those of a sixth-century Egyptian papyrus, which states that the daily barley ration for a cavalry

⁴⁹ Walker (1974), 18

⁵⁰ Plut. *Mar.* 13.1-2

⁵¹ Walker (1974), 18

horse was 1/10 of an *artaba*⁵² (approximately one-third of a *modius*, or 3 kg), results in a monthly ration of approximately 90 kg per horse and a yearly ration of 1,080 kg per horse, corresponding well with the figures listed by Polybius.

Determining an estimate of the yearly rations for one man and one horse raises the question of just how many men and horses there were in the Roman army. Again, these figures are subject to much debate and speculation, and the ancient military sources do not clarify the issue. The general consensus, however, suggests that the emperor Augustus revised numerous military statutes following his accession, one of which was a set definition of an Imperial legion's size as 4,800 men (as opposed to the legions of the Republic, the size of which could fluctuate every year according to the available manpower).⁵³ The double-strength first cohort, also added at around the same time, increased the size of the legion from 4,800 men to 5,280.⁵⁴ This included infantry, cavalry, artillery, and specialists such as surgeons and engineers, but probably not noncombatant slaves and attendants.⁵⁵ This new organization also resulted in an army that was designed around the grain supply rather than the reverse being true, a practice that greatly simplified the logistic provisions of the legion. The smallest division of the new legion, the *contubernium*, or eight-man squad, received one *modius* of grain per day (at 1 kg per man, with some left over). This makes the accounting of the legions' grain supply that much easier, as a century (ten *contubernia*) received 10 *modii* per day, a single-strength cohort (six centuries) received 60 *modii*, while the double-strength first

⁵² *P. Oxy.* 2046

⁵³ Roth (1994), 361

⁵⁴ Roth (1994), 354

⁵⁵ Roth (1994), 361

cohort received 120 *modii*.⁵⁶ A legion (nine standard cohorts and one double-strength) received 660 *modii* per day.⁵⁷ Therefore, each legion needed 5,940 kg of grain per day. This results in a theoretical demand for 2,168,100 kg of grain per legion per year. At the height of the Empire, in the second century A.D., the army totaled approximately 28 legions,⁵⁸ which would require 60,706,800 kg of grain per year. Reducing this to tons for simplicity's sake yields roughly 61,000 metric tons per year to feed the legionary soldiers alone.

The size of the auxiliary forces of the army is much less easily defined. Tacitus mentions that there were at least as many auxiliary troops as legionary, and also mentions the difficulties present in recounting the precise number of them.⁵⁹ This estimate, for the late first to early second centuries A.D., puts the total number of auxiliary troops at between 145,000 and 150,000 men.⁶⁰ Unit types and strengths within auxiliary regiments were more varied than corresponding legionary units, and Pseudo-Hyginus provides some details regarding these individual units.⁶¹ A unit could be classified as a *cohors peditata* (an infantry cohort), a *cohors equitata* (an infantry cohort with a cavalry detachment), or an *ala* (a cavalry regiment), sometimes with a further designation of *quingenaria* (single-strength), or *miliaria* (double-strength). Tacitus, then, has a point when he describes the difficulty of enumerating the auxiliary forces; multiple types of unit of varying strengths and composition complicate accounting. Coello provides a

⁵⁶ Roth (1994), 362

⁵⁷ Roth (1994), 362

⁵⁸ The army increased to 33 legions under Septimius Severus in the third century A.D.

⁵⁹ *Ann.* 4.5: "...and there were also in suitable places in the provinces allied fleets and cavalry wings and auxiliary cohorts, nor were they much different than [the legions] in strength of men, but to make an accounting of them is uncertain, for according to the demands of the time they would relocate to here and to there, or they would sometimes increase in number or be reduced."

⁶⁰ 28 legions of roughly 5,000 men each

⁶¹ Ps. Hyg. *De Mun. Castr.* 16-28

summary of the available data regarding the sizes and numbers of auxiliary units during the Empire, which provides the basis for Table 3 below:

Table 3: Total Number of Auxiliary Units⁶²

	<i>Number of Men</i>	<i>Number of Units</i>	<i>Total Men</i>
<i>Ala Quingenaria</i>	528	90	47,520
<i>Ala Miliaria</i>	792	10	7,920
<i>Cohors Peditata Quingenaria</i>	480	127	60,960
<i>Cohors Peditata Miliaria</i>	800	18	14,400
<i>Cohors Equitata Quingenaria</i>	608	130	79,040
<i>Cohors Equitata Miliaria</i>	1,040	22	22,880

Based on this arithmetic, it seems that the total number of auxiliary soldiers in the Roman army was approximately 233,000 men. This would be far greater than Tacitus's unspecific and vague figure (assuming the highly unlikely proposition that these units were always at full strength), and such a number would demand a little more than 75,000 metric tons of grain per year for the soldiers. This results in a total grain demand for the men of the Roman armed forces (legionary and auxiliary) of roughly 136,000 metric tons per year.

It is even more difficult to calculate the number of horses and other animals the army needed to feed. Since cavalry horses are the only animals that are explicitly mentioned with regard to fodder and rations, and since warhorses must be fed a certain amount of grain in order to stay fighting fit, it is reasonable to deal with them first. For the majority of the first and second centuries A.D., the cavalry forces of the Roman military fell into three major designations: the legionary troop (of approximately 120 troopers)⁶³, the

⁶² See Coello (1996), 2-4 for discussion of unit sizes and totals

⁶³ Davies (1989), 153

auxiliary units called the *ala* (cavalry only), and the *cohors equitata*, (mixed infantry and cavalry), each of which received the further designation of *quingenaria* (single-strength), or *miliaria* (double-strength). An auxiliary diploma of approximately 122 A.D.,⁶⁴ issued by the emperor Hadrian and comprising a list of all the auxiliary units stationed in Britain at the time may shed some light on the numbers of horses required by each unit. Based on the units listed in this document, Hyland makes a rough calculation of the number of horses for the units stationed in Britain, and her findings show that four legions' cavalry troops account for approximately 1,312 horses, including officer's mounts and replacement animals. It follows that an estimate for the total horses for a legionary troop would be 328 horses. Twelve *alae quingenariae* account for 6,720 horses (plus officer's mounts and replacements), so one *ala quingenaria* would command 560 horses. One *ala miliaria* would account for 1,120 horses, including officer's mounts and replacements. Fourteen *cohortes equitatae quingenariae* would account for 1,848 horses; so a single *cohors quingenaria* would comprise 132 (including officer's mounts and replacements). Finally, four *cohortes equitatae miliariae* would account for 1,056 horses; and a single *cohors miliaria* comprised 264 horses, including officer's mounts and replacements.⁶⁵ Extrapolating the admittedly rough and theoretical data found in the diploma of Hadrian to the rest of the units stationed throughout the empire is summarized in Table 4:

Table 4: Total Numbers of Cavalry Horses⁶⁶

	<i>Number of Horses per Unit</i>	<i>Number of Units</i>	<i>Total Number of Horses</i>
<i>Legion</i>	328	28	9,184
<i>Ala Quingenaria</i>	560	90	50,400
<i>Ala Miliaria</i>	1,120	10	11,200

⁶⁴ *CIL* 16.65

⁶⁵ See Hyland (1990), 89 for detailed calculations.

⁶⁶ Based on Hyland (1990), 89 and Coello (1996), 2-4

<i>Cohors Equitata Quingenaria</i>	132	130	17,160
<i>Cohors Equitata Miliaria</i>	264	22	5,808

In theory, there were a grand total of at least 93,752 warhorses for cavalry units alone. This number would have needed 101,252,160 kg, or roughly 101,000 metric tons of barley rations per year. This only accounts, however, for the cavalry horses. Accounting for the number of pack and draft animals employed by the army is made more difficult by the scarcity of references to them in the ancient sources. These pack and draft animals moved all the military gear and baggage that was not carried by the soldiers themselves. A rough estimate of the numbers of pack animals can be inferred from the fact that each eight-man *contubernium* had at least one mule to carry the unit's communal gear, such as its tent and mill-stone.⁶⁷ This would account for 600 mules per legion, and with an additional 120 mules to carry both the cavalry troopers' extra gear and the officers' baggage, (and including some 70 replacement mules) gives 790 mules per legion to carry soldiers' gear alone.⁶⁸ Mules were also used to pull the legion's artillery. Vegetius says a legion's complement of 55 *ballistae* needed 110 mules to haul them,⁶⁹ not counting the roughly 160 animals needed to carry the extra ammunition.⁷⁰ A single legion would therefore require approximately 1,060 total mules. Assuming a similar ratio of pack animals for the auxiliary regiments, a *cohors peditata quingenaria* would have commanded 160 mules, and a *cohors peditata miliaria* 320 mules.⁷¹ An *ala quingenaria* would have roughly 275 mules, an *ala miliaria*, 550, a *cohors equitata quingenaria* 230

⁶⁷ Roth (1999), 77

⁶⁸ Roth (1999), 83

⁶⁹ *Mil.* 2.24

⁷⁰ Roth (1999), 84

⁷¹ Roth (1999), 85

mules, and a *cohors equitata miliaria* 460 mules.⁷² Determining the number of draft animals engaged in pulling baggage wagons is impossible, since it is not known exactly how many baggage wagons were required or how the numbers of them compared to the numbers of pack animals.⁷³ Varro says that all road transport in the Roman world was moved by mule-cart, one of which required a team of two mules, so the number of wagons employed by the army would have added even more mules on top of the figures quoted above.⁷⁴ It is likely that armies in peacetime needed to maintain fewer pack animals than armies on the march; however, it is also likely that the soldiers stationed on the frontier needed to maintain at least some complement of pack animals in order to be ready to engage an enemy. Mules were also usually expensive; Columella says that a good mule could cost as much as a prized racehorse,⁷⁵ so it would have been more cost-effective to keep at least a few mules on hand, rather than trying to buy them up when they were needed.

The fodder for pack animals and that for cavalry horses was no doubt handled separately, and it was the pack animals that were most likely to suffer fodder that was of poor quality or insufficient quantity, or both. In theory, the pack mules associated with the ancient military can be totaled as follows:

Table 5: Total Numbers of Military Mules

	<i>Number of Mules per Unit</i>	<i>Total Number of Units</i>	<i>Total Number of Mules</i>
<i>Legion</i>	1,060	28	29,680
<i>Cohors Peditata Quingenaria</i>	160	127	20,320
<i>Cohors Peditata</i>	320	18	5,760

⁷² Roth (1999), 85

⁷³ Roth (1999), 87

⁷⁴ *Rust.* 2.8.5

⁷⁵ *Rust.* 6.27.1. Varro also says that good breeding stock for the best mules can sell for 300,000-400,000 sesterces. *Rust.* 2.8.3

<i>Miliaria</i>			
<i>Cohors Equitata Quingenaria</i>	230	130	29,900
<i>Cohors Equitata Miliaria</i>	460	22	10,120
<i>Ala Quingenaria</i>	275	90	24,750
<i>Ala Miliaria</i>	550	10	5,500

These figurative totals produce approximately 126,000 pack mules in the service of the Roman army. Unfortunately, the ancient sources do not specify any amounts for the grain rations of pack animals, but comparative modern evidence suggests that a mule should receive between 3 and 4 kg of barley per day, though they often received less in practice than was recommended in theory.⁷⁶ About 2 kg of barley per day would be sufficient to maintain a mule's health.⁷⁷ Therefore, if the pack mules were receiving a comparable amount of barley in antiquity, the theoretical barley needs for the army's pack mules would total approximately 252,000 kg of fodder per day, or roughly 92,000 metric tons per year.

In theory, then, the army required at least 136,000 metric tons of wheat and at least 193,000 metric tons of barley per year. Although the figures used to arrive at these totals may be speculative, they do provide a useful benchmark for estimating the army's demand on the grain reserves of the Roman Empire.

While calculating the total grain requirements of the military seems fairly straightforward (at least in theory), the logistical system through which these rations were obtained is still subject to debate. One central issue of this debate is whether the government obtained the majority of its grain requirements by purchase on the open

⁷⁶ Roth (1999), 65

⁷⁷ Roth (1999), 66

market (like any other buyer), or through forced purchase at a reduced rate, taxation-in-kind, levies on various parties; or some combination of these methods.

Roth argues that the military relied almost exclusively on the open market to obtain its supplies, purchasing them with large amounts of cash obtained by taxation.⁷⁸ Taxes were commonly paid to the government in cash, and the accounting records from Vindolanda, for example, all refer to cash payments made by the commander for supplies and services.⁷⁹ This system of purchase relied on private contractors, *negotiatores*, and private merchants engaged in the grain supply in exchange for incentives such as tax breaks.⁸⁰ While these private individuals no doubt serviced the military in some regard (military camps provided a catalyst for economic growth in the civilian markets, see epigraphical evidence for *conductores*, “contractors” working with the military⁸¹) there is no clear evidence that they were involved in military supply on any scale larger than the occasional supplementation of provisions that were acquired largely by taxation or purchase by government offices. Purchase on the civilian market undoubtedly played a role in the grain supply; for example Pliny mentions purchase of grain by the imperial treasury in his panegyric to Trajan.⁸² It seems, however, that this does not refer to open-market purchase at market price, but rather to the practice of *frumentum emptum* (“bought grain”), by which the state purchased grain at a fixed price, often lower than the market rate. Egypt provides some more evidence about this practice; the price at which the state purchased grain generally appears to be eight *drachmae*, less than market-price, and papyri indicate that barley was often purchased from collective communities in a

⁷⁸ Roth (1999), 238

⁷⁹ Cherry (2007), 730

⁸⁰ See *CIL* 13.7836, 8725 for references to grain merchant *negotiatores* on the Rhine frontiers.

⁸¹ Cherry (2007), 730

⁸² *Pan.* 29.5

particular district.⁸³ It appears that in cases of large-scale purchase, the grain is bought directly from a community or communities, rather than from private merchants, making this more like a form of taxation than anything like purchase on the free market.⁸⁴ There is, however, no evidence that the farmers from whom the army obtained its supplies suffered financially by doing business with the army rather than on the free market.⁸⁵ If the army administration was predominantly paying for its supplies in cash, rather than by some other means, the impetus to minimize supplemental costs, such as transport, would likely be increased.

Erdkamp asserts that the army relied more on in-kind taxation to obtain its grain supply, as opposed to purchase.⁸⁶ The Roman government had adapted Hiero of Syracuse's taxation-in-kind system on Sicily when it took over the island in 242 B.C., and the sources indicate the presence of taxation-in-kind in Egypt, Africa, Mauretania, Bithynia, and Pannonia,⁸⁷ all provinces with substantial agricultural production. Regular levies of grain are also mentioned in the sources; for example, Tacitus refers to Agricola's reforms of an in-kind tribute system which had become a burden on some communities,⁸⁸ and the *Codex* similarly addresses discrepancies among the taxes owed by certain communities.⁸⁹ Given that the cost of rations was deducted from the soldier's pay, however, at least until the third century A.D., it seems unlikely that the soldiers were provided with their rations in grain exacted as in-kind taxes.⁹⁰ Large contributions of

⁸³ *P. Amh.* 107

⁸⁴ See also *PSI* 7.797 and *P. Grenf.* 1.48

⁸⁵ Cherry (2007), 731

⁸⁶ Erdkamp (2002), 48

⁸⁷ Erdkamp (2002), 59

⁸⁸ *Agr.* 19.4

⁸⁹ *Cod. Theod.* 11.1.22 also indicates that the taxes must somehow be transported, suggesting that they were taxes-in-kind.

⁹⁰ Cherry (2007), 730

grain by communities or individuals seem to be limited to active campaigns, when the army was passing through or in winter quarters in territories without a more reliable supply infrastructure in place.⁹¹ The considerable rent of the vast imperial estates must have also played a role in the military supply; it is likely that these revenues went directly to supply the military, and a papyrus from Dura Europos mentions that an imperial official issued barley to the soldiers (probably for their horses) “from the profits of the imperial finances”.⁹² In Late Antiquity (probably between the reign of Septimius Severus and the compilation of the *Codex Theodosianus* in the fourth century A.D.⁹³), the empire adopted a new system called the *annona militaris* (“the grain supply for the soldiers”), a direct taxation-in-kind on the provinces that was specifically destined for the use of the army.⁹⁴ This system possibly arose from the reorganization of the army into smaller units stationed throughout the empire, rather than the earlier practice of stationing the majority of the army on the frontiers, and it eliminated the earlier practice of deducting the cost of rations from a soldier’s pay; rations were now issued to the soldiers free of charge.⁹⁵ It is likely that this new system further encouraged local supply, as obtaining these in-kind taxes of grain from communities near the forts would reduce the burden of transporting it long distances, which was one of the complaints the citizens of Britain had against taxation-in-kind before Agricola reformed the British system.⁹⁶ However the necessary supplies of grain were obtained, it is evident that the Roman authorities controlled vast

⁹¹ Erdkamp (2002), 58, 60-65

⁹² “ex praedis fiscalibus”, *P Dura*. 64

⁹³ Rickman (1971), 278

⁹⁴ Roth (2002), 384

⁹⁵ *Cod. Theod.* 7.4 reveals the complicated bureaucracy of officials, receipts and account books needed to operate this system.

⁹⁶ Tac. *Agr.* 19.4

reserves of this commodity, and put them to use in two major ways: to supply the city of Rome, and to supply the needs of the military.

The exact workings of the administrative system through which the army was provisioned is, like so many aspects of military supply, difficult to reconstruct, as are the identities and responsibilities of the particular officials involved. The ancient sources which mention the administration of provisions provide an incomplete picture, and a consensus on the nature of the logistical system of the military is notably lacking. It seems, based on the sheer volume of provisions that the army required, that a centralized agency in charge of military accounting was critical to the smooth functioning of the supply system. The exact nature of that agency, however, as well as its subordinates or how exactly it interfaced with provincial government or the unit-level administrators, remains unclear.

It has been suggested that the *praefectus annonae* (“the prefect of the grain supply”), the officer of the imperial cabinet directly responsible for the supply of grain to Rome for the civilian grain dole, may also have played a role in the military grain supply, and that this office was not merely responsible for civilian grain supply at Rome, but for the empire-wide supply of grain.⁹⁷ Indeed, the centralized office of the *annona* would have provided a useable framework for military accounting as well as civilian. Roth, however, argues that there is little direct evidence to support the use of the governmental office of the *annona* as a military institution, and that giving one official control over the food supplies of both the capital and the military would not have been in the interest of the

⁹⁷ Erdkamp (2002), 53

emperor's desire to maintain control of the necessities of the state.⁹⁸ Casson argues further that the grain trade was completely in the hands of private enterprise, and that government officials such as the *praefectus annonae* and even the emperor himself had very little to do with trade at all, citing the *ad hoc* methods employed for dealing with grain shortages and price-fixing as evidence of the lack of a standardized government office or protocols in charge of the grain trade.⁹⁹ Several inscriptions from Rome dating to the first century A.D. attest to officials who are *a copiis militaribus* (“in charge of military supplies”), usually freedmen of the imperial household.¹⁰⁰ They were probably some sort of financial officers responsible for military accounting or for coordinating the military account books, and the fact that all of the inscriptions that mention them were found in or near the city of Rome seems to support the idea that they functioned under the auspices of a centralized military accounting office. Rickman theorizes that these officials operated under another imperial cabinet official, the *procurator a rationibus* (“the procurator in charge of the accounts”), who was in charge of the total military payroll.¹⁰¹ This official mainly accounted for weapons and forts,¹⁰² though he most likely supervised payroll deductions for state-supplied rations as well. Like most procurators, the *a rationibus* came from a military rather than a legal background.¹⁰³ He was probably in charge of collecting the supply reports and account books from the provinces and passing their information on to the emperor, who, from the institution of the *aerarium militare* (the military treasury) under Augustus,¹⁰⁴ was solely responsible for allocating money

⁹⁸ Roth (1999), 264

⁹⁹ Casson (1980), 24

¹⁰⁰ *CIL* 6.8538, 8539, 8540, 2840

¹⁰¹ Rickman (1971), 273

¹⁰² *Stat. Silv.* 3.98

¹⁰³ Roth (1999), 263

¹⁰⁴ *Dio Cass.* 55.25.2-5, 56.33.3

and supplies to the military. This may be a more plausible chain of command for military supply than the civilian officers of the *annona*. According to the *Historia Augusta*, the emperor Hadrian made a point of carefully reviewing provincial supply reports and having good grasp of the necessities of military supply.¹⁰⁵ While there must have been an official bureau responsible for military accounting and provisions, at least in respect of financial accounting, control of the military's provisions was centralized on the national level at Rome in the hands of the emperor and his cabinet officials.

At the provincial level, the variety of administrative systems (imperial versus senatorial provinces, client kingdoms, and the unique administration of Egypt) make constructing a chain of command difficult. In most cases, it seems that the mechanisms of the military grain supply were under the jurisdiction of the provincial governor. Dio Cassius mentions that a governor in Spain was expelled from the Senate for failing to provide enough grain to soldiers in North Africa;¹⁰⁶ and Tacitus notes that as governor of Britain, Agricola reformed the regulations governing the military grain supply in Britain and lightened the burden of the civilians who supplied the grain.¹⁰⁷ A selection from the *Digest* under the reign of Hadrian refers to the authority of provincial governors, legionary commanders, and procurators to dispatch representatives to make purchases. This authority must encompass military provisions, since legionary commanders are mentioned alongside civil administrators.¹⁰⁸ The *praefectus Aegypti* ("the prefect of Egypt"), that province's gubernatorial equivalent, also had the authority to collect provisions; Amherst Papyrus 107 states that the prefect ordered the collection of barley to provision a cavalry regiment

¹⁰⁵ SHA, *Hadr.* 10.8-11.1 Maybe one of the more reliable sections of the HA: Dio Cassius also confirms Hadrian's interest in the provision of military supplies, Dio. Cass. 71.2.3

¹⁰⁶ 60.24.5

¹⁰⁷ *Agr.* 19

¹⁰⁸ *Dig.* 39.4.4.1

stationed within the province.¹⁰⁹ Clearly, the chief political and fiscal authority of supplying the military with grain rested with the governor's office.¹¹⁰ The military payroll within the provinces, and most likely the attendant deductions made for a soldier's rations, was managed by the provincial *procurator*, the representative of the imperial treasury.¹¹¹ This procurator was also responsible for collecting taxes and revenue,¹¹² so it was likely he was also concerned with exacting the in-kind taxes of grain that the government drew from its various possessions, some of which no doubt went towards feeding the army. The typical background for a procurator also appears to be military (as opposed to the legal careers of many other administrative offices) and it makes sense that a military veteran would be the best candidate to manage military supply and payroll. Indeed, Strabo confirms the procurator's role in the military supply, noting that they are specifically responsible for provisioning the soldiers.¹¹³ Mentions of provincial procurators in this role continue until the third century A.D., when the institution of the *annona militaris* would have taken over much of the procurator's duties.¹¹⁴

Regardless of the exact nature of the state agency responsible for allocating grain, the necessary reserves would still have to be collected and transported to some extent, as well as stored once they reached their final destination. The transport and storage of grain raise several special issues, which will be addressed in the following section.

¹⁰⁹ *P. Amh.* 107

¹¹⁰ Adams (1999), 125

¹¹¹ Strab., 167

¹¹² Dio Cass., 53.15

¹¹³ Strab., 3.4.20

¹¹⁴ See for example Plin., *Epist.* 10.27 and *IGR* 3.739 for the office under Trajan, *CIL* 13.107 for the office under Severus Alexander.

Distribution: Transport and Storage

Grain, in comparison to many of the other foodstuffs included in the military diet, presents unique problems of transport and storage. Loose grain is a heavy, bulky, and awkward material to transport; it takes on the properties of a fluid when stored in bulk, flowing to fill space and exerting considerable pressure on its storage containers. Loose grain piled to a height two meters exerts a vertical downward pressure of approximately 12,000 kg per square meter, and a lateral thrust of up to two-thirds that amount.¹¹⁵ In addition to this, grain continues to take in oxygen and release carbon dioxide, heat, and water after it is harvested, and so must be kept as dry and cool as possible to prevent rot or insect infestation.¹¹⁶ The ideal storage conditions are at a temperature of below 15 °C and humidity of less than 10-15 percent, which must be maintained throughout the transport process, as well as during storage, to keep the grain edible.¹¹⁷

The transport of loose grain in bulk, in some instances perhaps hundreds or thousands of tons at a time, was a costly proposition. Diocletian's *Edict on Maximum Prices*, though presenting data for the fourth century A.D. and therefore subject to the considerable contemporary rates of inflation from the earlier empire, is nevertheless a useful tool for estimating the costs of transporting bulk commodities such as grain. Transport on land, namely by wagons which held roughly 60 *modii* of wheat priced at 100 *denarii* per *modius*, was subject to a 12 *denarii*-per-kilometer surcharge.¹¹⁸ According to these figures, a wagonload of wheat could be expected to double in price after a trip of 480

¹¹⁵ Rickman (1980b), 261

¹¹⁶ The dangers of spontaneous combustion or explosion that are concerns of modern grain storage do not appear to have been a major concern.

¹¹⁷ Rickman (1980b), 261

¹¹⁸ Jones (1964), 841

km.¹¹⁹ Grain transport by sea, in comparison, especially on long voyages such as the approximately 2,700 km from Alexandria to Rome, was much less costly; subject only to a 16-*denarii-per-modius* surcharge.¹²⁰ A comparable 60 *modii* of grain on a sea voyage from Alexandria to Rome would increase in price only by 960 *denarii*, compared to the increase of 6,000 *denarii* for wagon cartage over a fifth of that distance. The tariff rate for the longest sea journey of the ancient world, from Syria to Lusitania (modern-day Portugal), roughly 5,000 km given the circuitous routes involved, was only 26 *denarii-per-modius*.¹²¹ It was therefore far cheaper to ship grain by sea from one end of the Mediterranean to the other (and some distance beyond) than it was to cart it much shorter distances overland, despite the numerous risks associated with sea travel. Grain, on account of its special requirements and the sheer amount of it which was moving around the Roman world at any one time, had to move by water whenever possible (by sea, river, or canal) to keep the cost of the shipping manageable.

The Roman state, so far as is known, did not employ a merchant marine of any kind, meaning that the shipments of grain and other commodities were usually undertaken by private individuals. These individuals fell mainly into two categories: either a person who employed a ship that he did not own to conduct his own commerce (*negotiator*), or the captain or operator of the ship itself (*navicularius*, who may or may not have been the ship's owner, the terminology is unclear); and in some cases, these could be one and the same.¹²² Columella says that transport contracts were regularly sold to these private merchants and shippers by the state, especially in the cases where the transport was that

¹¹⁹ Jones (1964), 841

¹²⁰ Jones (1964), 842. The tariff on shiploads represents a percentage of the sale price, rather than a cost of transport as with wagonloads.

¹²¹ Jones (1964), 842

¹²² *CIL* 12.4393, for example. S. Fadius Musa appears to have been a *navicularius* who operated his own trading business as a *negotiator*.

of provincial grain tithes.¹²³ Under the Empire, the *praefectus annonae* appears to have been responsible for arranging and letting out these contracts with private merchants,¹²⁴ at least as far as the civilian grain supply for the city of Rome was concerned. Special circumstances outside the realm of official contracts could also arise; for example, the emperor Claudius guaranteed full compensation for lost revenue to merchants who were willing to make risky winter shipping runs of grain during an emergency shortage at Rome.¹²⁵

Evidence for the procedures and mechanisms for shipping are limited in many cases. In Sicily, for example, the Republican tax collectors were obligated to bring their collected grain tithe to a seaport, but the mode of transport is not specified.¹²⁶ In North Africa in Late Antiquity, transport of grain to seaports was carried out by the *cursus clabularius*, a system of oxcart routes maintained in equal measure by the state and the private landowners.¹²⁷ In Egypt, however, the rigidly organized bureaucratic structure of provincial government provides more substantial evidence of the government bookkeeping entailed by the grain supply. It appears that Egypt had a highly organized process (consisting of trains of pack animals, ferries, and large river barges) for getting the grain from the local fields to harbors on the Nile, and from there to the granaries in Alexandria where it awaited shipment under the authority of the Roman officials.¹²⁸ Detailed receipts were issued for every stage of the transport process, in triplicate copies that were distributed between the shipper, the *sitologos* (the official who supervised grain shipments for a particular district), and to the *strategos* (the senior administrative official

¹²³ *Rust.* 1.praef.20

¹²⁴ *Dig.* 14.1.1.18

¹²⁵ *Suet. Claud.* 18

¹²⁶ *Cic. Verr.* 3.14.36

¹²⁷ The state furnished the wagons and the landowners provided the oxen and furnished their upkeep.

¹²⁸ Rickman (1980a), 121

of the district), both to protect those involved from liability and to prevent fraud.¹²⁹ As another safeguard against fraud, sealed and signed samples of the cargo (called *digmata*) were often transported along with the shipment, to ensure that nothing untoward happened to the grain en route, and that it arrived at its destination in an appropriate condition.¹³⁰ It seems that similar samples were also used at the seaports of Rome in the fifth century A.D., which could indicate that they were used not only on the journey to Alexandria, but also on the long trek from Alexandria to Rome.¹³¹

Moving grain shipments around the empire demanded huge numbers of transport ships, barges, and wagons. The emperor Claudius passed legislation in the first century A.D. to encourage the building of grain ships, in which the minimum limit set for capacity was 10,000 *modii*, or about 90 metric tons, which appears to be the smallest ship considered useful for grain shipment.¹³² Grain freighters were usually much larger, though, and by the second century A.D. the standard capacity had increased to 50,000 *modii*, about 450 metric tons, though the original 10,000 *modii* minimum limit was still in use. It seems that ship owners who could provide at least a 450-tonner, or several 90-tonners, were exempt from compulsory public service.¹³³ The grain demands of the city of Rome for example, mainly those of the governmental grain doles to the population, would have accounted for almost 360,000 metric tons of grain per year: 800 shiploads of 450 metric tons, or 4,000 shiploads of 90 metric tons.¹³⁴ The *Isis*, a second-century A.D. grain freighter used in the Egyptian grain fleet, had a capacity of roughly 1,100 metric tons

¹²⁹ *P. Oxy.* 1259 provides an example of such a receipt.

¹³⁰ *P. Oxy.* 708 describes a cargo of wheat that was found to have been tampered with by mixing in dirt and barley.

¹³¹ *Cod. Theod.* 14.4.9

¹³² Gaius, *Inst.* 1.32c

¹³³ *Dig.* 50.5.3

¹³⁴ Rickman (1980b), 263

(according to the writer Lucian's description of her dimensions¹³⁵), and it is likely that most of the ships bringing grain from Alexandria were of comparable size. Though these average overall capacities of the freighters are known, the shapes, layouts, or sizes of their holds, or details of how grain was stored in them is not.¹³⁶ Unlike wrecks of ships carrying *amphorae*, which allow reconstructions of how the containers could be stacked in the hold, cargos of grain are much harder to visualize. As previously stated, grain must be kept dry in transit, both because damp grain will spoil, and because wet grain expands and could damage the ship. Grain must also be kept from shifting in the hold, as this could capsize the vessel. Filling the hold completely with loose grain would keep it from shifting, but would require a full load to be transported every time, as well as a sustainably watertight hold. The Digest contains a reference to grain poured in a hold of a common ship, and is mainly concerned with the differentiation of multiple people's properties; referring to separation of the cargoes with planks, partitions, or separate containers (whether sacks, bins, crates, jars, or other containers is not specified).¹³⁷ This suggests that such a method of subdividing the hold with wooden partitions could be used for grain transport.¹³⁸ It is known that grain was unloaded by porters, or *saccarii*, so called because they carried sacks of cargo. Though whether this cargo was transported entirely or merely unloaded in sacks is not clear, transport in sacks makes sense as a method that would both keep the grain dry and prevent it from shifting.¹³⁹ Grain could also conceivably be transported in *amphorae* or *dolia*, though this would sacrifice both space and weight considerations.

¹³⁵ *Navig.* 5

¹³⁶ Rickman (1980a), 133

¹³⁷ *Dig.* 19.2.3

¹³⁸ Rickman (1980b), 265

¹³⁹ Rickman (1980a), 134

Once the grain had been shipped by sea, other transportation methods came into play to move it from the seaport to other destinations. In the case of areas with navigable rivers, barges and smaller ships could shuttle the grain from city to city, as with the intermediate transport of grain from the harbors at Ostia to the storehouses in Rome. In areas where such rivers were not available, wagons or other cartage methods would be used. The *naves codicariae*, the small river craft used to shuttle grain up the Tiber from Ostia to Rome, seem to have had an average capacity of between 54 to 63 metric tons, or roughly 6,000 to 7,000 *modii*.¹⁴⁰ These ships had to be towed upriver, since the Tiber's winding course made it difficult to sail, and so the trip from Ostia to Rome (approximately 35 km), could take as long as three days.¹⁴¹ The ox carts employed by the *cursus clabularius* in North Africa could carry approximately 50 to 75 *modii*, or roughly 450 to 675 kg each.¹⁴² These carts could average approximately 3 km per hour.¹⁴³ Teams of pack animals, such as donkeys or mules (or camels, in areas where they were prevalent) could move faster, approximately 5-6 km per hour, though more of them would be required to carry equivalent weights of grain.¹⁴⁴ For example, to carry the same amount of grain as would fit in an ox cart, one would need four to seven donkeys (carrying approximately 80-100 kg apiece), or three to five mules (carrying approximately 150-180 kg apiece).¹⁴⁵

Once the grain reached its final destination, it was stored in a building specifically designed for this purpose. Roman granaries were shaped by the demands of storing this delicate commodity, and so present easily recognizable profiles. The weight and bulk of loose grain called for thick, sturdy walls and floors, and the necessary moisture and

¹⁴⁰ Rickman (1980b), 267

¹⁴¹ Rickman (1980a), 19

¹⁴² Rickman (1980b), 264

¹⁴³ Rickman (1980a), 14

¹⁴⁴ Rickman (1980a), 14

¹⁴⁵ Raepsaet (2008), 589

temperature conditions under which grain must be stored demanded efficient drainage and ventilation, as well as provisions to keep out insects, birds, and rodents. The large communal granaries of Roman establishments took two distinct forms, the military granaries and the civil storehouses,¹⁴⁶ which differed mainly in their layout, overall size, and primary function (military granaries stored if not only then primarily grain, while civil storehouses could store many types of goods). It is the military granaries that this paper will examine in detail.¹⁴⁷

Much of the recent excavation of military *horrea* has taken place in Britain and Germany, and it is these buildings, due to their substantial and durable construction, that form the most significant remains in many military sites, along with the *principium*, the garrison headquarters. Studies have also brought to light the remnants of timber *horrea* dating back to the first century A.D., where previously the only examples of military granaries were the first stone granaries dating to the time of Trajan.¹⁴⁸ Indeed, the similarities between German and British military granaries—by no means the only surviving examples, but perhaps the best-known and most-studied—attest the standardization of the building form. Wherever the army was stationed, the granary was likely to be very similar in construction. In fact, it seems that this layout dates back at least as far as Scipio’s siege of Numantia in 134 B.C. and seems to have been based on much older examples from Pergamum in the third-century B.C.¹⁴⁹ The building is most often long and rectangular, consisting of a single large room. Sizes varied considerably; the smallest excavated granary, at Croy Hill in Britain, is roughly 14 meters long by 5

¹⁴⁶ The Latin word *horreum*, “storehouse”, “barn”, or “granary” is used to refer to both of these buildings.

¹⁴⁷ See Rickman (1971) for an in-depth examination of civil *horrea*.

¹⁴⁸ Rickman (1971), 213

¹⁴⁹ Rickman (1971), 2

meters wide, and the largest, at Niederbieber in Germany, is roughly 53 meters long by 16 meters wide.¹⁵⁰ The floors were raised and supported by pillars or dwarf walls (the arrangement of which varies from site to site), and ventilation provided by a system of vents that allowed air to circulate in the hollow space beneath the floor.¹⁵¹ The walls are exceptionally thick (often 1-1.5 meters) and often buttressed, to counteract the force of the grain on the building.¹⁵² Military *horrea* were almost exclusively single-story buildings, though some later renovations to a select few sites may show evidence of the later addition of a second story.¹⁵³ The roofs of stone granaries were usually tiled, whereas timber granaries were roofed with planks or shingles, and the roofs typically had long overhanging eaves to keep water runoff away from the foundations.¹⁵⁴ The construction and maintenance of the fort's granary was the responsibility of the provincial governor.¹⁵⁵

Specific information about the storage capacity or interior arrangement of these buildings is very hard to determine, as most of the remains are of the exterior walls and floor supports, rather than the interior structures. It has been suggested that the grain was stored in wooden bins that lined the length of the building, with a corridor down the middle, but conclusive evidence has not been found.¹⁵⁶ It is equally conceivable that the grain was stored in containers, such as baskets or sacks, which would have been the most

¹⁵⁰ Johnson (1983), 144

¹⁵¹ Johnson (1983), 145

¹⁵² Johnson (1983), 149

¹⁵³ Rickman (1971), 236

¹⁵⁴ Johnson (1983), 153

¹⁵⁵ *CIL* 7.732

¹⁵⁶ Such bins would have needed to be keyed into the floors somehow in order to support the force of the grain on the bin walls, but evidence of this, such as slots cut into the flagstones of granary floors, has not been found. Johnson (1983), 156

convenient method for both storage and distribution.¹⁵⁷ Although the main purpose of the *horreum* was the storage of the unit's grain supplies, the interior conditions and heavy construction of the building would have made it a good place to store many different types of provisions. The dark, cool, well-ventilated, and vermin-proofed granary may also have functioned as a kind of cold storage for other foodstuffs.¹⁵⁸ There are references in the ancient sources to a device called a *carnarium*, a frame with a series of hooks that could be hung from the ceiling,¹⁵⁹ used in kitchens. The reconstructions of military granaries show that there was considerable space among the rafters for such a device to be employed in military *horrea* as well, to hang joints of salted or dried meat or other foods.¹⁶⁰

Tacitus mentions that, as governor of Britain, Agricola stocked up the forts in of the province with one year's worth of supplies.¹⁶¹ This suggests that it was not usual for forts to be so well-supplied, and raises the question of how much grain a fort's granary could hold. Obviously, this would depend on the strength of the garrison, and Richardson takes this into account in his construction of a numerical relationship between garrison strength and granary floor area.¹⁶² He calculates that a year's wheat for a man (at 1 kg per day) would occupy about 0.5 cubic meters, and a year's barley for a horse would occupy about 1.7 cubic meters.¹⁶³ Based on the sizes of currently-known granaries, Richardson concludes that a year's supply for an infantry unit alone could, in fact have been

¹⁵⁷ Johnson (1983), 156. Storage in this way would also allow moisture and heat to dissipate faster than other storage methods.

¹⁵⁸ Johnson (1983), 157

¹⁵⁹ Cato, *Agr.* 13.1, Varro., *Rust.* 2.4.3.

¹⁶⁰ See for example the reconstruction of the timber granary at Baginton, Johnson (1983), 157

¹⁶¹ *Agr.* 2.22

¹⁶² Richardson (2004), 432

¹⁶³ Richardson (2004), 431

contained in the typical single-story granary.¹⁶⁴ A cavalry unit, however, due to the higher volumes of barley that it would need to keep in reserve, would have needed either regular replenishment, even though their granaries were usually around 50 percent larger in terms of floor area.¹⁶⁵ The variation in floor area among granaries also seems to suggest that some forts could be used as grain depots for others in the area. This would have the advantage of keeping the grain nearer to the fields, which would reduce the risk of spoilage in transit, and it seems that some infantry forts had extra space in their granaries relative to their garrison size, perhaps to keep grain for cavalry forts.¹⁶⁶

The grain stored in the unit's granary, was gradually divided up among the soldiers as part of their daily rations. This process involved several administrators at the unit level, who are mainly known from epigraphic evidence at the forts themselves.¹⁶⁷ While the degree to which the units could have supplied themselves locally is still debated, if they had the resources to do so at hand, it would have simplified logistical operations to have obtained what resources they could from as close to the fort as possible.

Allocation: A Soldier's Rations

The state-provided staples of a soldier's ration, including grain, were furnished in exchange for a deduction from the soldier's pay, *ad victum*, literally "towards food", at least until the institution of the *annona militaris*. A late first-century A.D. papyrus from Nicopolis in Egypt¹⁶⁸ concerning the pay record of two specific soldiers gives the deduction for food as 80 *drachmae* per trimester (the armies were paid three times a year

¹⁶⁴ Richardson (2004), 435

¹⁶⁵ Richardson (2004), 435

¹⁶⁶ Richardson (2004), 439

¹⁶⁷ See below, pp. 60-61

¹⁶⁸ *RMR* 68

in January, May, and September¹⁶⁹), or 240 *drachmae* per year, which amounts to approximately 27% of their total annual pay at this time.¹⁷⁰ There are, however, no comparably detailed records from elsewhere in the empire, and so it is impossible to say whether these data hold true for other soldiers.¹⁷¹

The commanding officers of the garrisoned units often functioned as military accountants or quartermasters.¹⁷² It is not known how these commanding officers related to the provincial government and its authority to procure provisions, but it seems that there was at least some cooperation. Sparse epigraphic evidence shows that there were some connections between the officials that served the unit and provincial administration: for example, military accountants in the governor's staff who had previously served under the camp prefects of a legion and vice versa.¹⁷³

Thanks to a larger surviving body of evidence, in the form of military inscriptions, the administration of logistics at the unit level is much better understood. Legionary tribunes and their auxiliary counterparts (infantry tribunes and cavalry prefects), in addition to their tactical duties, supervised foraging and requisition and monitored the grain supply of the unit to counteract fraud.¹⁷⁴ The camp prefect, *praefectus castrorum*, also played a role in military logistics. Although Vegetius's description of this office only mentions its responsibility for a sufficient number of pack-animals, wagons, firewood, and straw,¹⁷⁵ it is likely that the camp prefect also handled the day-to-day logistical administration of the

¹⁶⁹ Tac. *Ann.* 1.17

¹⁷⁰ At this time, soldiers received approximately 225 *denarii* per year in regular pay, and exchanging this into an equivalent amount of *drachmae* (at the Alexandrine standard of 4 *drachmae* to 1 *denarius*, used in Egyptian currency of the Roman period) results in 900 *drachmae* per year. See pp. 155 in D.R. Walker (1976). *The Metrology of the Roman Silver Coinage Part I: From Augustus to Domitian*. Oxford. B.A.R. Supplementary Series 5.

¹⁷¹ Southern (2006), 110

¹⁷² Roth (1999), 262

¹⁷³ See *CIL* 8.3292 for a gubernatorial accountant at a legionary camp.

¹⁷⁴ *Dig.* 49.16.12.2

¹⁷⁵ *Mil.* 2.10

unit, as well as management of the payroll and rations.¹⁷⁶ Inscriptions also mention various officials operating at the unit level, probably reporting to or operating under the authority of the camp prefect. These titles were not necessarily ranks, and may not even have been permanent titles, and the chain of command into which they were incorporated is difficult to reconfigure. The *signifer* was the unit's banker, who tabulated pay deductions for provisions and kept track of the accounting for food.¹⁷⁷ The *mensores frumenti* ("measurers of grain") who were responsible for portioning out stored grain may have been either active military, as in one inscription,¹⁷⁸ or retired veterans working with the camp administrators.¹⁷⁹ It is likely that this title referred to an official who participated in the grain provisioning for the forts, since the *Digest* indicates that overseeing them was the duty of the unit commander.¹⁸⁰ The *librarii horreorum* ("clerks of the granaries") mentioned in the *Digest* were responsible for keeping track of stored grain and other provisions.¹⁸¹ These officers were most likely primarily accountants, working under the supervision of a superior officer (perhaps the camp prefect), but not intimately involved in the problems of provisioning.¹⁸² A few inscriptions from one fort in Africa mention *dispensatores*, who might have been slaves working with provisions,¹⁸³ but there is no further evidence from other forts to suggest that they were part of the large-scale administrative system, or indeed that they were involved with supplies at all. They may simply have been general clerks or accountants, a role in which literate slaves

¹⁷⁶ There is also a reference to a soldier being sent out to procure grain, "*ad frumentum*" by the camp prefect c. 80 A.D., supporting the theory that he was responsible for the food supply to the legion. *P. Gen. Lat.* 1

¹⁷⁷ *PSI* 9.1063

¹⁷⁸ *CIL* 13.7007

¹⁷⁹ *ILS* 9091

¹⁸⁰ *Dig.* 49.16.12.2

¹⁸¹ *Dig.* 1.6.7, where they are listed as *immunes*, exempt from daily duties.

¹⁸² Rickman (1971), 274

¹⁸³ *CIL* 8.3288-3291

were often employed; the title *dispensator* can mean a variety of things, from “steward” to “pay clerk”.¹⁸⁴ Officials called *actuarii* (“bookkeepers”) appear in the third century A.D., possibly connected to the institution of the *annona militaris*. These officials seem to have been recruited primarily from the soldiery, rather than civilian offices, and Vegetius emphasizes the need for soldiers to be linguistically and mathematically literate.¹⁸⁵

Whatever gaps existed in the state-run supply system must have been filled by officers at the unit level. It is clear that individual units were significantly involved in supplying themselves, which is not surprising given the immediacy of the need. Issues of time and cost would have encouraged the local supply of what was available from the vicinity in enough quantity to maintain the garrison’s supplies.

The military *prata*, or *territorium*, was an important source of land; inscriptions mention legionary *pratae* in Spain, Dalmatia, Pannonia, and auxiliary *pratae* in Spain.¹⁸⁶ Prior to around the mid-second century A.D., the military lands are referred to in inscriptions as *prata*, (“meadowland”), and after the mid-second-century, the lands are referred to as *territorium* (“domain”). This change in terminology could be driven by the evolution of the military relationship with the civilian landscape: *prata* could encompass extensive civilian settlements and farmlands, whereas *territorium* was explicitly set aside for military purposes.¹⁸⁷ It is almost impossible to determine conclusively the total size of these military-controlled lands. Local topography, weather, pre-existing civilian populations, and a number of other factors could have influenced the extent of a

¹⁸⁴ Rickman (1971), 273

¹⁸⁵ *Mil.* 2.19

¹⁸⁶ Elton, (1996), 67

¹⁸⁷ Mason (1988), 166

territorium. Current estimates range into the hundreds of square kilometers: Carnuntum and Aquincum on the Danube frontier could each have commanded at least 420 square kilometers, and as much as 750 square kilometers.¹⁸⁸ Boundary markers from a legionary *prata* in northern Spain suggest that the unit commanded roughly 560 square kilometers.¹⁸⁹ The minimum estimate for the *prata* of the fortress at Burnum in Dalmatia is roughly 325 square kilometers.¹⁹⁰ Mason concludes that forts in Britain could have had similar ranges, as much as 500 square kilometers in the cases of Lincoln and Gloucester, and between 350 and 400 square kilometers in the case of York.¹⁹¹

The sheer size of these appropriated lands suggests that the grazing of the unit's animals was not the only use to which the land was put.¹⁹² The Stobi Papyrus (a second-century A.D. duty roster of an auxiliary unit stationed in Macedonia), mentions a detachment of men sent across the Danube "to protect the crops", suggesting that military land on the frontiers could also be used for agriculture.¹⁹³ This record does not specify that the crops were being grown on the unit's own *territorium*, but the crops being defended were clearly destined for the garrison. Trajan's Column depicts Roman legionaries reaping grain themselves, but as this takes place during an active campaign, the conditions may be different to what the soldiers experience in peacetime.¹⁹⁴ While the soldiers might not have been engaged in agriculture themselves, it would make sense for them to lease their lands out to civilian tenant farmers in exchange for a portion of their

¹⁸⁸ Mason (1988), 168

¹⁸⁹ *CIL* 2.2916

¹⁹⁰ *ILS* 5968

¹⁹¹ Mason (1988), 170, 185

¹⁹² Mason (1988), 165

¹⁹³ *P. Stob.* 31

¹⁹⁴ i.e., soldiers on campaign would have had to obtain food wherever they could on their own initiative, whereas soldiers in garrison had more secure resources at their disposal. Scene 109.291

agricultural produce.¹⁹⁵ This would encourage local agriculture and cut down on the cost of supply incurred by the government. It was also common for soldiers to be sent on missions to procure supplies; Pliny mentions soldiers dispatched in order to get grain from Paphlagonia,¹⁹⁶ the records of Dura Europos detail soldiers on grain missions, and the Stobi Papyrus mentions troops sent to Gaul for grain and also some “at the grain ships” (what this means is not readily apparent, but it seems that it could possibly refer to soldiers either collecting a shipment of grain, or placing an order for a new shipment).¹⁹⁷ In Egypt, soldiers also supervised grain shipments on the Nile, though it seems that this was mainly to ensure that the grain arrived in Alexandria in the same state and quality in which it had left the fields.¹⁹⁸ While it is ultimately unknown to what extent the unit was involved in its own provisioning, conjecture seems to indicate that the most cost- and labor-effective option was to obtain as much of the necessary supplies as possible from the lands closest to the garrison.

Where this chapter has laid out the system of grain provisioning on an empire-wide scale, the following target a more localized and concentrated view of the grain supply. The next three chapters represent case studies of three particular forts in three disparate frontier zones; Haurra in present-day Jordan, Vindolanda in Britain, and Vindonissa in present-day Switzerland, all of which have substantial surviving evidence for permanent granaries. The goal of these case studies is to examine the grain requirements of these three forts based on the surviving granary structures and garrison information, and then to construct a model of local grain supplies. Through examination of the amount of grain

¹⁹⁵ Mason (1988), 167

¹⁹⁶ *Epist.* 10.27

¹⁹⁷ *P. Stob.* 18, 33

¹⁹⁸ See *BGU* 3.802, *SB* 6.9223, *P. Oxy. Hel.* 14

that could conceivably be supplied by the surrounding areas, it should be possible to demonstrate that these forts could sustain at least some of their grain stores from the surrounding land, and that to do so would both ensure the accessibility of the necessary reserves and represent the most cost-effective means of maintaining the necessary supplies.

Chapter Three: The Fort at Haurra (Humayma)

The Roman fort at ancient Haurra is the earliest-dated surviving fort in the region, constructed immediately after Trajan's annexation of the province of Arabia in A.D. 106.¹ The main purpose of the fort appears not to have been purely military occupation, but rather policing and supervising the new Roman highway, the Via Nova Traiana, which ran between Bostra (modern Bosra) and the Gulf of Aqaba; as well as the water resources of Haurra. The civilian settlement at Haurra, founded by a Nabataean king (either Aretas III or Aretas IV), in the first century B.C., is the most significant civilian settlement in the Wadi Hisma,² and its location was likely influenced both by the traditional caravan trade routes that passed through the area, and the available natural resources—namely access to water. Haurra is situated in a catchment area surrounded by sandstone *jebels*, escarpments that funnel rainwater runoff to the site, and is also within reach of a spring fed by the winter rain and snowmelt in the higher elevations to the northwest.³ The town also has access to fields of arable land to the north and east of the settlement, and these factors made the site the most hospitable location for a permanent settlement. The success of the civilian settlement and the resources it commanded no doubt motivated the installation of the Roman garrison, following the annexation of the former Nabataean kingdom.

The fortress at Haurra would have supported a unit of approximately 500 men. The original garrison may have been a *vexillatio*, a legionary detachment, from the Legio VI

¹ Oleson (2007), 535

² Eadie & Oleson (1986), 50

³ Eadie & Oleson (1986), 50

Ferrata, based in Caparcotna (also simply called Legio) in Palestine.⁴ At some point in the second century A.D., this unit was replaced by a similar detachment from the Legio III Cyrenaica, based in Bostra,⁵ as shown by an inscription found in the town.⁶ Numismatic evidence suggests that the fort was temporarily abandoned between the late third and early fourth centuries A.D., possibly due to either the political unrest in the empire at the time, or to Diocletian's reorganization of the frontier armies and fortifications in the east. A unit of *equites sagitarii indigenae* ("native-born mounted archers"), probably an auxiliary unit recruited locally, also appears to have been stationed at the site in the fourth century A.D., and is listed in the *Notitia Dignitatum*.⁷ By the beginning of the fifth century A.D., however, the fort was abandoned and some of its construction materials reused for the Byzantine-era buildings at the site.

Granary Structure

Examples of excavated military granaries in the Near East are far less common than similar examples in Britain or Germany, and so the granary at Haurra is especially useful. The granary conforms to the construction standards for Roman military granaries, with substantial stone walls roughly 1.1 to 1.2 meters thick. The building is situated in the northeast quadrant of the fort, east of the *principium*, on the main east-west road of the fort, and near the western gate to provide easy access. Between the road and the fort, there is a large courtyard paved with sandstone slabs, which probably functioned as a loading dock for the granary, or as the distribution area for the soldiers' rations.⁸

⁴ Parker (2000), 124

⁵ Parker (2000), 124

⁶ Oleson (2010), 59

⁷ *Or.* 34.25.

⁸ Oleson et al. (2008), 325

Buttresses support the eastern and western walls, but in the case of the west wall, these buttresses appear not to have been part of the original construction, but rather a later addition.⁹ This may be the result of an effort to repair damage incurred during the early-fourth-century abandonment phase, when the sloping ground and the lateral thrust of the roof began to destabilize the western wall.¹⁰ The building appears to have been laid out as a rectangle of roughly 22.5 meters wide by 25 meters long (roughly 75 Roman feet by 85 Roman feet), subdivided into three smaller rooms, each roughly 7.5 meters wide by 15 meters long (25 Roman feet by 50 Roman feet).¹¹ These dimensions are in keeping with the granaries of similar-strength units; for example, Ambleside and Gelligaer in Britain, both housing *cohortes quingenariae* of roughly 500 men.¹²

The westernmost room of the Huarra complex is floored with terracotta tiles, in contrast to the sandstone slabs used in the other two rooms, and a drain was built into the floor of this room with access to an exterior conduit.¹³ This may suggest that the western room was used to store other foodstuffs than grain, and that the other two rooms were the granaries proper.¹⁴ Military granaries were often paired (either as two separate buildings on either side of the principium, or as two buildings side-by-side), and stone-built granaries were often constructed as a double-sized building.¹⁵ This type of arrangement could be expressed either as two buildings centered around a courtyard, such as at Caerhun and Ambleside in Britain, or as two rooms sharing a central wall, such as at

⁹ Oleson et al. (2008), 325

¹⁰ Oleson et al. (2008), 325

¹¹ Oleson (2007), 541

¹² Gentry (1976), 32

¹³ Oleson et al. (2008), 325

¹⁴ Oleson et al. (2008), 325

¹⁵ Johnson (1983), 144

Benwell in Britain and Saalburg in Germany.¹⁶ If the western room at Huarra was intended for the storage of other goods (perhaps liquids, such as wine or olive oil),¹⁷ then the central and eastern rooms would fit this pattern of double-size stone granaries sharing a central wall. If this were the case at Huarra, the total floor area for the two granary buildings would have been 225 square meters.

With this in mind, it is useful to apply information derived by Richardson for relating granary floor area to garrison size, in order to determine how much of the unit's yearly grain could be stored here.¹⁸ Based on a study of granaries in Britain, Richardson theorizes that a year's supply of grain for a 500-man infantry unit, such as the one stationed at Huarra, occupied roughly 2,500 square feet (roughly 232 square meters), or that each man was allotted five square feet (roughly 0.5 square meters, stacked to a height of 1.5 meters) of storage for his annual ration.¹⁹ If Richardson's calculations hold true for Huarra, the granaries could hold a yearly supply of grain for roughly 450 men. This would be approximately the size of a single military cohort, which was nominally 480 soldiers.²⁰ If the unit had horses, however, Richardson suggests that a man's yearly ration (of both wheat for himself and barley for his horse) would occupy roughly 7.5 square feet (0.7 square meters).²¹ In this case, the granary at Huarra could hold a year's supply for only about 330 men, requiring that a cohort of 480 to be resupplied more than once a year. Archaeozoological evidence from Huarra does reveal the presence of equids,

¹⁶ Johnson (1983), 144

¹⁷ Oleson et al. (2008), 325

¹⁸ See Richardson (2004), Appendix 3, pp. 441

¹⁹ Richardson (2004), 429

²⁰ Coello (1996), 1

²¹ Richardson (2004), 434

though in rather small numbers,²² and it has not yet been determined whether these equids were horses (unlikely, given the relative delicateness of horses with regards to diet, weather conditions and water resources, and the scarcity of appropriate grazing in the area) or donkeys (more likely, as these would be better suited to the dry conditions and relatively limited grazing of a desert environment). Camels are also present in the archaeological record, in larger numbers, and primarily in the fort during the Roman period.²³ These animals would not have required much grain fodder, as they were adapted to the grazing of the desert environment. Evidence from Berenike in Egypt, from the first to second centuries A.D., suggests that camels were occasionally fed barley, though only when local grazing was insufficient.²⁴ It seems increasingly likely that camels, rather than horses, were the main military mount for any cavalry soldiers the garrison might have employed.²⁵

The interior of the Hauarra granaries were finished in keeping with the storage concerns particular to grain. The interior walls were heavily plastered and the wall plaster was extended over the join between wall and floor. Both Columella and Varro mention the use of either marble or clay plaster in finishing the interior of granaries, and Columella recommends that the plaster cover the joint between the walls and the floor.²⁶ This would both seal the granary against moisture seepage and eliminate the cracks between the stones which could harbor insects or admit mice and other vermin. Since both marble and a suitable source of clay were lacking at Hauarra, the walls were finished

²² Oleson (2010), 44. Equid remains represent only about 0.50 percent of the total animal remains, and roughly 4.30 percent of the remains whose species have been identified.

²³ Finnegan (in prep.), 20

²⁴ Cappers (2006), 90

²⁵ Finnegan (in prep.), 20. Especially for the *equites sagitarii indigenae* of the fourth century A.D.

²⁶ Col., *Rust.* 1.6.9, Var. *Rust.* 1.57.2

with a hard, sandy plaster that could be produced in the area.²⁷ The floor was not elevated, but this was not unusual in the case of stone-built granaries, as the construction materials would provide for adequately low temperatures and reduced moisture without the added airflow.²⁸ It is also possible that desert conditions reduced the risk that moisture would damage the grain, so that forts in the desert regions would have had fewer concerns of grain spoilage than forts in areas with more temperate climates. Stone-built granaries without subfloor ventilation systems typically use flagged or tiled floors, and this is seen in the granaries at Haurra.²⁹

Though excavated granaries in the Near East are rare, perhaps because of the tendency of military units to be based in urban centers rather than in distinct fortresses as in the West,³⁰ the granary in the legionary fortress at Lejjun, some 250 km to the northeast, provides some comparison to the granaries at Haurra.³¹ The fortress at Lejjun is later in date than the fortress at Haurra, having been built in the early fourth century A.D. (possibly as part of the frontier reorganization that influenced habitation patterns at Haurra) and abandoned in the mid-sixth century.³² Despite the time difference, the granary at Lejjun still conforms to the standardization of the building form established centuries earlier.

The granary at Lejjun is roughly 25 meters wide by 25.5 meters long (85 Roman feet by 85 Roman feet).³³ Its location is somewhat strange for a military granary: instead of being centrally located near the *principium*, the granary is isolated in the southwestern

²⁷ Oleson et al. (2008), 325

²⁸ Johnson (1983), 149

²⁹ Johnson (1983), 149

³⁰ Parker (2006), 111

³¹ This site is not to be confused with Lejjun in Palestine, the modern site of Caparcotna/Legio

³² Parker (2006), 111

³³ Crawford in Parker (2006), 235

corner of the fortress. It was still accessible to cart traffic by means of the western and southern gates. Also, unlike the free-standing granary buildings at Hauarra, Lejjun's granary is built abutting the western fortification wall of the fortress. This location is at the highest elevation of the site, and perhaps this consideration influenced the location of the granary, as this position would facilitate the drainage of water away from the building.³⁴ The orientation of the Lejjun granary also differs from the orientation of the granary at Hauarra; at Lejjun, the long axes of the granary rooms are oriented east-west, whereas at Hauarra they are oriented north-south. This seems to subscribe to Varro's recommendation that a granary should be oriented with an eastern or a northern aspect, so that breezes can aerate them.³⁵ While the granary at Hauarra shows no provisions for subfloor ventilation, the granary at Lejjun demonstrates some evidence that an elevated wooden floor was installed within the stone structure.³⁶ There is also evidence that there may have been ventilation shafts cut into the walls near the ground level, and the combination of the raised floor and the ventilation shafts would have allowed for subfloor ventilation.³⁷ It is possible that the difference in layout of the two granaries demonstrates a difference in local wind patterns, used to ventilate and cool the granaries.

Lejjun's granary is also divided into three parallel rooms, of roughly the same dimensions as the rooms at Hauarra, though only the central room has an exterior doorway. The central room is linked to the other rooms by smaller interior doorways, whereas at Hauarra, each room has its own door.³⁸ There does not appear to be a difference in the construction of any one room, (as there is, for example, in the unique

³⁴ Parker (2006), 118

³⁵ *Rust.* 1.57.2

³⁶ Crawford in Parker (2006), 239

³⁷ Crawford in Parker (2006), 239

³⁸ Crawford in Parker (2006), 239

flooring arrangement of the westernmost room at Huarra), so it is not possible to conjecture that certain rooms were used for the storage of other foodstuffs apart from grain. The central doorway at Lejjun offers access to the granary by way of a paved square like the one at Huarra, and the doorway was originally wide enough to allow small carts to enter the central room.³⁹ The doorway appears to have been reduced in size at some point (from 3.7 meters wide to 2 meters wide), perhaps indicating that cart access was no longer a priority. The interior dimensions of these rooms, roughly 8 meters wide by 23 meters long (25 Roman feet by 75 Roman feet) in the case of the central room; and 6.5 meters wide by 23 meters long (20 Roman feet by 75 Roman feet) in each of the two side rooms, would provide roughly 483 square meters of floor area, more than twice that of the granary at Huarra, and capable (according to Richardson's figures) of storing a year's supply of grain for roughly 965 infantrymen, or roughly 690 cavalrymen. If only the two side rooms were being used to store the grain, as might be suggested by the fact that these two rooms open onto the central room rather than having their own external access points, the floor area for storage would be reduced to roughly 299 square meters, enough space to support roughly 598 infantrymen, or 427 cavalrymen. Lejjun is situated in an area of much better potential agricultural productivity, having access to similar soil and farming resources,⁴⁰ while receiving between 200 and 400 mm of rainfall per year, in contrast to Huarra's 80 mm.⁴¹ in contrast to Huarra's 80 mm, so it seems that grain agriculture in the area of Lejjun could have been even more substantial than it was at

³⁹ Crawford in Parker (2006), 239

⁴⁰ Parker (2006), 11-13

⁴¹ Parker (2006), 12

Hauarra.⁴² Like Hauarra, it is likely that Lejjun also depended on locally-sourced grain reserves.

Local Grain Production

Several factors must be considered in the construction of a model of local grain growth for Hauarra in the Roman period. Access to water, nutrient content of the soil, and the availability and fertility of arable land governed the supply that could be obtained from the vicinity. The location of Hauarra must have been influenced by these factors. The site has easy access to deposits of agriculturally viable soil that could be sufficiently irrigated by run-off, and even the modern-day inhabitants of the area produce cereal crops.

Archaeobotanical samples taken from the settlement areas of Hauarra show that cereals were cultivated on the site in antiquity. Domestic, or six-rowed barley (*hordeum vulgare*) seems to be the most abundant domestic cultivar, and both bread wheat (*triticum aestivum*) and another unidentified type of wheat appear in a few soil samples.⁴³ Barley tolerates both drought and soil salinity well, and takes a relatively short time to harvest, suiting it to arid, saline soils with short rainy seasons, such as those found in desert environments.⁴⁴ Grain was certainly being grown at Hauarra in antiquity; archaeobotanical samples reveal not only the remains of the grain plants themselves, but also the weeds associated with cultivated cereal fields and the byproducts of grain processing.⁴⁵ It seems likely that the garrison at Hauarra could rely on at least some of their grain supplies being locally-sourced.

⁴² Parker (2006), 12

⁴³ It makes sense that barley would appear more frequently than wheat; if barley were being processed for human consumption, it would need to be roasted beforehand to remove the hull, which would result in the charring necessary to preserve the grains.

⁴⁴ Cappers (2006), 48

⁴⁵ Ramsay (in prep.), 44

Water is always the most important consideration when undertaking agriculture in a desert environment. As discussed in Chapter Two, an absolute minimum of 250 millimeters of rainfall per year is needed for successful germination of grain sprouts. In the modern day, the highest elevations of Jordan (the central mountain ranges at 1,500 meters or above) receive the highest rainfall, on average between 250 and 300 mm of precipitation annually. The highlands around Hauarra, at between 1,000 and 1,300 meters, receive an average of 100 to 200 mm.⁴⁶ Hauarra itself receives only about 80 mm of annual rainfall.⁴⁷ Both cereal cultivation and pasturing of animals, however, take place near the site, indicating the presence of sufficient supplies of water for both these pursuits.⁴⁸ The presence of numerous Nabataean cisterns and reservoirs in the ancient civilian settlement of Hauarra (some of which are still in use today), also suggest that a careful system of water management ensured sufficient reserves of water in antiquity.

The period between the early first century B.C. and mid-third century A.D. in ancient Jordan might also have had more significant supplies of water than it does today. For example, ancient Arabic literary sources mention running water in desert regions, and archaeological remains of Roman-era bridges, piers, and wells are visible in areas in which there is no water today.⁴⁹ Rabbinical sources also mention high crop yields in the Levant during the first century A.D.⁵⁰ A cooler and moister climate phase beginning in roughly the ninth century B.C. might have contributed to increased forest growth and to increased human settlement of the region.⁵¹ Chemical tests on ancient timbers recovered from Masada in Judaea also suggest that these trees lived in a climate that was cooler and

⁴⁶ Shehadeh (1985), 23

⁴⁷ Oleson (2010), 31

⁴⁸ Eadie & Oleson (1986), 50

⁴⁹ Shehadeh (1985), 27

⁵⁰ MacDonald (2001), 376

⁵¹ Jobling (1984), 194

less arid; their composition is consistent with trees from a more humid region.⁵² Plant evidence from Hauarra also reveals the presence of various weeds (such as sedge grasses and sorrels) that typically grow in damp or marshy environments, suggesting sufficient water to support these plants.⁵³ Nabataean rock art in the southern region of Jordan dating to roughly the first century B.C. depicts several species of large herbivores, such as cattle, horses, and ibex, which imply both sufficient drinking water and sufficient grazing to support such animals.⁵⁴ The exact nature of the paleoclimate of Jordan is still debated, but these sources seem to imply a greater level of available water and a cooler, more agriculturally favorable climate for Jordan in antiquity.

In addition to natural rainfall, the settlement at Hauarra had access both to the complex system of Nabataean cisterns built to supply the town, and to the Nabataean aqueduct that funneled water down to the settlement from springs in the higher elevations.⁵⁵ The water management system at Hauarra also included earthwork and stone barriers, which directed runoff into carefully managed runoff fields, in order to preserve the water in the soil in preparation for cereal farming.⁵⁶ This carefully constructed system of water management ensured that as much of the available precipitation and run-off as possible was redirected toward the settlement area. Today, the entire catchment area of Humayma, some 206 square kilometers, receives on average roughly 391,000 cubic meters of runoff per year (roughly 1,900 cubic meters per square kilometer).⁵⁷ An estimated 7,143 cubic meters of this water would have been diverted to the numerous cisterns and intended for human and animal consumption, in addition to the approximately 1,900 cubic meters of

⁵² MacDonald (2001), 375

⁵³ Ramsay (in prep.), 43

⁵⁴ Oleson (2010), 36

⁵⁵ Oleson (2007), 537

⁵⁶ Oleson (1997), 176

⁵⁷ Oleson (2010), 32

water supplied to the town's and fort's reservoirs by the aqueduct, which also brought in an additional six cubic meters per hour. Subtracting the capacity of the cisterns from the annual runoff leaves approximately 383,000 cubic meters per year available for agriculture or other needs.⁵⁸ Even in a dry year, when the runoff only provides roughly 280,000 cubic meters, there would still be 272,000 cubic meters of runoff available for other purposes. The runoff field to the north of the settlement for example, roughly 1.5 km long by 1 km wide, could expect roughly 2,850 cubic meters of runoff in an average year. This would be more than enough to support healthy cereal crops, even factoring in the likely loss of much of this total to evaporation and seepage. Ancient Hauarra's prime location on the drainage tracks of the sandstone escarpments may have given it access to even more runoff in antiquity. Even today, cereal farming near Humayma depends solely upon the soil moisture provided by winter runoff for cultivation, and no artificial irrigation is employed.⁵⁹

Many of the practices of dry-farming common to ancient Greece and Italy would not have been effective in the area around Hauarra.⁶⁰ Leaving the land fallow in alternate years in order to preserve the moisture of the soil would have been problematic due to the speed with which the water drained through the sandy soil down into the inaccessible strata of the regional geology.⁶¹ Intercultivation with trees, (specifically olive trees), another method of preserving soil moisture common to ancient Italian and Greek dry-farming,⁶² was also not generally feasible at Hauarra. Large numbers of trees, although their roots reach deeper and could conceivably access water that grain could not,

⁵⁸ Oleson (1997), 176

⁵⁹ Eadie & Oleson (1986), 55

⁶⁰ White (1970), 173

⁶¹ Oleson (2010), 33

⁶² White (1970), 173

nevertheless require more water than grasses to survive. Large-scale artificial irrigation of crops would have been similarly impractical. There is evidence that small-scale irrigation of a few trees and some vegetable patches was practiced, and both the small vineyard in the Roman period and the sizeable grove of olive trees in the Islamic period would have required some irrigation as well.⁶³ In general, winter runoff could be expected to supply the majority of the water necessary for agriculture.

In addition to adequate water resources, the soil of a particular region must be of appropriate quality (in both nutrient content and in water retention) in order to foster successful cereal agriculture. The Hisma region around Hauarra is characterized by the presence of numerous dry prehistoric lakebeds, filled with light, sandy loess and loam, which provide more hospitable conditions for agriculture than other areas of the desert.⁶⁴ Both plowing and the germination of grain are easier in lighter soils such as this, as opposed to the heavier, more claylike soils of central Europe.⁶⁵ While the light, sandy soil would retain water better than the nearby rocky areas, and so could likely have held sufficient water to support a mature crop of grain; it would also need more frequent watering, as water drains more quickly from sandy soil than it does from heavier soil.⁶⁶ Agriculture on this soil either demands careful water management, or limits sowing to the areas which are sufficiently watered by the winter precipitation of that year, as is the modern practice. The soil near Hauarra is a mix of sand, loam, and loess in varying proportions, resulting in similarly varied agricultural viability.

⁶³ Oleson (2010), 403

⁶⁴ Henry (1987), 23

⁶⁵ White (1970), 180

⁶⁶ Oleson (2010), 33

Soil samples taken from the area around Hauarra show that the land could sustain a significant level of agricultural cultivation, a higher level, in fact, than expected in a desert area.⁶⁷ The soil chemistry is more favorable than might be expected of a desert region: pH is slightly alkaline, but still neutral enough that grain plants would perform well, soil salinity is somewhat elevated but still within manageable level, and the essential nutrients for plant life—calcium, magnesium, and potassium—are high in most of the soil samples from Hauarra.⁶⁸ The nitrogen and phosphorus content, however, is low; and in the case of phosphorus, somewhat lower than would be expected of desert soil, particularly desert soil which had never been farmed before.⁶⁹ This would seem to indicate that the available phosphorus in the soil around Hauarra might have been depleted by farming in antiquity, though low levels of phosphorus would nevertheless result in low yields for cereal farming.⁷⁰ Phosphorus and nitrogen can be reintroduced to the soil by the use of organic fertilizer, such as manure. If herding practices at Hauarra in antiquity were similar to what they are in the region today, where the animals were grazed on the stubble left in the fields after the grain harvest in the summer, this would provide a source of manure to refresh the soil. Based on water resources, the region of Hauarra could have supported roughly 3,000 sheep or goats, and roughly 300 camels or donkeys,⁷¹ which would produce a significant amount of manure. Manuring in the dry desert climate, however, tends to be ineffective, both because the animals which provide the manure must range over a wide area to find sufficient food through grazing, and because manure dries out too quickly for the nutrients to be properly infused into the

⁶⁷ Oleson (1997), 177

⁶⁸ Oleson (2010), 356

⁶⁹ Oleson (2010), 357. Virgin arid soils typically have a phosphorus content of perhaps 20 times the proportion found at Hauarra.

⁷⁰ Oleson (1997), 177

⁷¹ Oleson (2010), 402

soil.⁷² It is possible that farmers in antiquity could have worked the manure into the soil when it was available, either by tilling or by relying on the animals themselves to work the soil with their hooves, but the fact remains that a dry climate and relatively infertile soil would adversely impact the effectiveness of manuring or other fertilization methods to refresh the soil. Manuring is not used in modern farming on the site (though animal dung is collected and dried for fuel), so it seems that the grain cultivation of ancient Hauarra would have been limited by the poor nutrient content of the soil to small yields. Several soil samples also lack the necessary organic matter and microorganisms necessary for plant life, both because of the dry environment and because desert soil is slow to devolve from rock into soil in the process by which organic matter is generated.⁷³ The absence of organic matter further complicates successful agriculture, because it drastically decreases the potential fertility of the soil in question. Given sufficient water resources, soil fertility is the main limiting factor in modern-day desert wheat cultivation, and it is likely that the situation has not changed drastically from what it was in antiquity.⁷⁴

The civilian population of Hauarra, as determined from the available water resources in the town, was probably around 450 people at most. The arrival of the 500-strong Roman garrison would have been an adjustment for the native civilians—almost doubling the population of the settlement overnight—but there is little evidence that the addition had any profound effect on the daily life of the civilian population.⁷⁵ This suggests that the town and landscape of Hauarra was able to support such an increased population without

⁷² Oleson (1997), 178

⁷³ Oleson (2010), 356

⁷⁴ Bruins (1986), 92

⁷⁵ Oleson (2010), 50

significant upheaval. Though the grain consumption rate for the soldiers is known from the historical sources in the form of their daily rations, the average grain consumption of a civilian is not. The amount of grain that a civilian would require can, however, be generally estimated based on theoretical distribution rates. Ancient sources record grain distributions to the general population, such as the *frumentationes* at Rome, but the figures provided by these documents are subject to much speculation. For example, the monthly grain dole at Rome handed out five *modii* per recipient per month, but it is unknown whether this amount was intended for one person or a whole family, or whether it represented the sole source of grain or a supplementary source.⁷⁶ For the Greek world, one *choenix* (equal to roughly 0.1 *modius*, or 0.8 kg) per man per day is the generally accepted rate of grain consumption.⁷⁷ This equates fairly well with the daily ration of a Roman soldier given by Polybius: roughly one kg per man per day.⁷⁸ While assigning this consumption rate—that of a very active adult male—to the entire population of Haurra is perhaps an overestimate, without specific knowledge of the region's ancient demography it is impossible to generate a more specific estimate.⁷⁹ If the civilians at Haurra were consuming grain at a theoretical rate of 0.8 kg per day, they would have required roughly 131 metric tons of grain each year. Added to the 162 metric tons of grain per year consumed by the garrison (and assuming that this entire amount was locally sourced), this totals 293 metric tons per year for human consumption. The garrison at Haurra, though it probably did not have horses, would likely also have had to account for fodder for its pack animals as well, given the limited grazing available in the

⁷⁶ Foxhall & Forbes (1982), 41

⁷⁷ Foxhall & Forbes (1982), 51

⁷⁸ 6.39.13. See also above, Chapter Two.

⁷⁹ See Foxhall & Forbes (1982), 49 for more detailed estimates of the consumption rates of a balanced population.

desert. This amount of necessary grain fodder could, of course, be significantly reduced by employing donkeys or even camels as pack animals, given the increased ability for these animals to survive on the limited and poor-quality grazing of a desert environment. A donkey would consume roughly 1.5 kg of grain per day, if it was being fed a full ration,⁸⁰ and a camel would need hardly any grain fodder at all. The present evidence, however, is not conclusive as to what kind of pack animals the garrison employed, and, given the Roman military preference for mules as pack animals (perhaps due to their increased carrying capacity compared to donkeys), the annual fodder requirements for a full complement of mules will provide a maximum benchmark for total fodder requirements. Assuming that the garrison kept its full complement of 160 mules, these animals would need roughly 320 kg of grain fodder per day, or roughly 116 metric tons per year.⁸¹ The total requirements of the inhabitants of Haurra, therefore, would be a minimum of 293 metric tons per year (if the garrison turned its pack animals out to graze rather than feeding them grain rations), and a maximum of 409 metric tons per year (if the garrison kept its full complement of pack animals and fed them a full grain ration).

Of course, considerations for crop losses in the field and in storage as well as reservations for the next year's seed must be added to this estimate. Sowing rates can help determine the reservations for seed grain, but crop loss figures are more speculative. Both Pliny and Columella make the same recommendation for sowing rates on dry, loose soil such as the type found at Haurra: four *modii* per *iugerum*, or roughly 136 kg per hectare.⁸² This may be a rather optimistic figure for sowing rates in Jordan, however, and it is not clear exactly what kind of soil Pliny and Columella mean when they refer to it as

⁸⁰ Roth (1999), 65

⁸¹ See above, pp. 42

⁸² *HN* 18.55.199, *Rust.* 2.9.5-6

“dry” and “loose”, though it is doubtful they are speaking of sandy desert soil like that found at Hauarra. Estimates of loss rates vary. Modern losses of barley and wheat crops, suffered by modern strains of these plants which are protected by artificial pesticides and herbicides, total roughly twelve percent of the crop.⁸³ The potential losses of these crops without chemical pesticides and herbicides have been calculated as almost half the crop, but it is unlikely that ancient plants regularly suffered such severe losses.⁸⁴ Ancient wheat and barley strains were hulled varieties, relatively protected from disease and pests by their outer shells, and some of the weeds that could potentially compete with the grain crops for resources were themselves edible, offsetting the losses of the grain.⁸⁵ Loss rates of grain in the field in antiquity, therefore, may have been more in line with the modern figures for chemically-protected crops, rather than the unusually high potential loss rates for these crops without modern pesticides and herbicides.⁸⁶ Losses to pests such as the grain weevils mentioned by the Roman agricultural treatises may have accounted for a loss of roughly ten percent of the crop, based on evidence from southern Britain in the Roman era.⁸⁷ Archaeological evidence for plant disease is scarce in the Roman period, suggesting that perhaps the strains of cereal plants cultivated by the Romans (emmer, spelt, and barley) were resistant or at least less susceptible to disease than, for example, grains of the Medieval period.⁸⁸ Richardson suggests a loss rate in storage of perhaps four percent of the harvest, once the grain had been stocked in a granary.⁸⁹ Assuming a loss in the field of ten percent (to pests and disease) and a loss in storage of four percent (to

⁸³ Gent & Dark (2001), 60

⁸⁴ Gent & Dark (2001), 60. They theorize that ancient grain plants were hardier and more resistant to disease and pests than modern strains.

⁸⁵ Gent & Dark (2001), 67

⁸⁶ Gent & Dark (2001), 66

⁸⁷ Gent & Dark (2001), 67

⁸⁸ Gent & Dark (2001), 69

⁸⁹ Richardson (2004), 438

vermin and spoilage), a total loss rate for a grain crop may be estimated as roughly fourteen percent of the crop.

Estimating the total area of land under cultivation at Hauarra is difficult, as the amount of arable land varies with the accessibility of water; in a dry year with less runoff, less land would conceivably be cultivated. The fields in which grain is grown in the modern period lie largely within a five-kilometer radius of the ancient settlement, which is typical of agriculture in the region.⁹⁰ The majority of the arable soil lies to the northeast and southeast of the settlement, on a 2.5 km radius from the town of Hauarra, and this radius would encompass roughly 4,000 hectares of the agriculturally-viable soil.⁹¹ While this is admittedly an idealistic estimate, it still shows that even with the wide variability in the agricultural conditions of the site, there was more than enough accessible arable land to support cereal farming.

The theoretical grain yield of this land is rather more problematic. The rate at which grain could be sown was based, at least in the opinions of the ancient agronomists, on the moisture content and texture of the soil. In terms of returns in desert cereal farming, highly helpful seventh-century A.D. papyri from Nizzana, in the Negev desert southeast of Hauarra, refer to the yields of wheat and barley for the area. Assuming the recommended four-*modii-per-iugerum* sowing rate prescribed for dry soils, these results show wheat yields of roughly 630 kg per hectare.⁹² These figures are consistent with modern-day farming in the area, which similarly depends on runoff for irrigation and on largely unfertilized soil to carry the crop.⁹³ If these figures hold true for Hauarra in

⁹⁰ According to the “principle of least effort”, see Oleson (2010), 35

⁹¹ Oleson (2010), 404

⁹² *P. Nizz.* 82, as discussed in Bruins (1986), 87

⁹³ Bruins (1986), 91

antiquity, roughly 465 hectares of land under cultivation would have supplied the minimum 293 metric tons needed to feed the human population at Haurra, both the civilians and the soldiers. In order to furnish the maximum requirements of both the humans and the military animals, 409 metric tons, a maximum 649 hectares would have provided the necessary crops. Assuming the same sowing rates, a minimum of roughly 100 hectares and a maximum of roughly 140 hectares of land would have been required to carry the seed grain for the next year. A further 65 hectares minimum and 90 hectares maximum would allow for a loss of fourteen percent of the crop as determined above. This totals a minimum of roughly 630 hectares and a maximum of roughly 880 hectares to provide the annual supplies of grain of Haurra. The roughly 4,000 hectares of arable soil that lie within the theoretical agricultural radius of Haurra could have more than supplied this amount, even if (as is likely) the yields were somewhat lower, or the area of land available for cultivation was reduced by a lack of runoff.

External Sources of Food

Due to the absence of viable water transportation methods in the desert, any grain which the garrison imported would have had to be brought to the site by carts or pack animals. Haurra's prime location near both short- and long-distance trade routes, particularly the Via Nova Traiana, would have made overland transport to the site easier. As the only significant settlement between Aila (modern Aqaba) and Petra, Haurra became one of the major way stations on the road, and probably took advantage of the trade coming from and going to the Red Sea. The presence of fish and marine shellfish remains at the site provides an example of such trade: these items are impossible to produce on-site. The varieties of fish and shellfish that are present suggest sources in the

Red Sea, and the frequency of marine animal remains is impressive given that they had to be transported from Aila.⁹⁴ Red Sea fish and shellfish have also been found at Mons Claudianus in the Egyptian desert, demonstrating that dried or salted seafood was often imported to desert settlements, particularly those with a military presence.⁹⁵ Though Hauarra was more easily accessed by overland transport than other sites in the region, and the importation of foodstuffs such as fish and shellfish show that overland trade did move through Hauarra, using these overland transport venues to bring grain to the site would still have been costly.

According to the *Edict on Maximum Prices*, a camel-load of grain was defined as roughly 270 kg, and the transport surcharge appended to camel transport was roughly 13 *denarii* per kilometer.⁹⁶ Transport by donkey or mule was cheaper, at only about 7 *denarii* per kilometer, but both of these animals can carry less than a camel. In terms of grain, loads would probably be shipped up the Judaeian coast from Alexandria, or perhaps down the coast of Asia Minor from the Black Sea, putting into port at Gaza or another Mediterranean seaport. This means that, theoretically, in traveling the roughly 190 km from Gaza to Hauarra, one camel-load of grain would incur 2,470 *denarii* in transport surcharges, according to the figures quoted in the *Edict*. The cost of transporting grain from the Mediterranean coast to Hauarra would therefore be more than its total value, according to the price listed in the *Edict* of roughly 66 *denarii* per *modius*.⁹⁷

⁹⁴ Oleson (2010), 48

⁹⁵ Van der Veen & Hamilton-Dyer (1998), 104

⁹⁶ Jones (1964), 841

⁹⁷ Admittedly, a highly speculative figure. Prices in the *Edict* are listed not in silver *denarii*, but in *denarii communes* (a notational currency for simplifying exchange rates), and are also subject to the high rate of inflation that characterized the currency of Diocletian's day. See Duncan-Jones (1974), 372 for the size of the *modius castrensis*, the measure of grain used in the *Edict*, equal to roughly 1.5 standard *modii*.

Pliny discusses the numerous costs that frankincense caravans might incur en route from the southern Arabian peninsula to Gaza, a journey of some 2,230 km. By his calculations, the customs tariffs, charges for fodder and water, and overnight lodging fees added up to 688 *denarii* per camel, or roughly 0.30 *denarii* per kilometer over the journey.⁹⁸ It is difficult to tell whether Pliny is also counting a similar per-kilometer transport rate to those quoted in the *Edict*. The figures in the *Edict* seem drastically high compared to Pliny's figures, and this is probably a reflection of the currency inflation that occurred between the first and fourth centuries A.D. It may also be that, rather than prescribing a set per-kilometer tariff rate for land transport, the prices in the *Edict* are meant to average out the same costs that Pliny describes (fodder, water, lodging, etc.) into a more manageable per-kilometer rate, to make accounting for different types and lengths of journeys easier. Pliny is also, of course, not describing the transportation of a staple, like grain, but rather a luxury commodity, frankincense, which may also be governed by different importation regulations and subject to different charges. Despite this difference in cargo, and despite the differences in currency between Pliny's account and the *Edict*, it is illustrative to set Pliny's transport rate of roughly 0.30 *denarii* per kilometer as the minimum transport cost and the *Edict*'s figure of 13 *denarii* per kilometer as the maximum rate, in order to establish the range of transport costs that the garrison at Haurra might conceivably face in importing its supplies of grain.

Applying these figures to Haurra shows that a great deal of expense could be avoided by producing as much of the annual supply of grain as possible on site. It would take roughly 600 camel-loads to transport the grain necessary for the sustenance of the unit. The minimum cost to import the 162 metric tons of grain consumed by the unit would be

⁹⁸ *HN* 12.32.65

34,200 *denarii*, and the maximum would be 1,500,000 *denarii*. Such costs make it unlikely that the unit imported the entirety of its necessary supply: but in a very bad year, when drought negatively impacted the agricultural production of the area, the garrison might be required to import some of their grain, though it is impossible to determine in what proportions.

Grain was not the only foodstuff which would incur transport costs, and evidence from Hauarra suggests that the soldiers or the locals were also involved in producing other foods for the use of the garrison. Archaeozoological evidence, particularly a high proportion of teeth and jawbones, suggests the presence of pigs at Hauarra in substantial numbers, consistent with many military sites.⁹⁹ Pig husbandry in the desert, however, presents special problems of shade and water supplies, since pigs do not sweat and can sunburn.¹⁰⁰ It is possible (and perhaps more likely, given the absence of any archaeological evidence of provisions made for pigpens or watering troughs for pigs) that the soldiers hunted or trapped local wild pigs, rather than employing domestic pig husbandry; but nevertheless, the preponderance of pig remains is clearly associated with the Roman fort and Roman occupation.¹⁰¹ Sheep and goats were also raised nearby, and goats in larger proportions than sheep, perhaps due to the limited grazing in the area.¹⁰² Lentils and chickpeas, olives, figs, and dates; ubiquitous elements of Near Eastern agriculture, also appear in the seed assemblages of Hauarra, and could have been produced locally.¹⁰³ Grapes also seem to be present in small amounts, and a wine-press found on the site would imply that efforts were made to produce even this commodity

⁹⁹ Finnegan (in prep.), 19

¹⁰⁰ Finnegan (in prep.), 20

¹⁰¹ Finnegan (in prep.), 20

¹⁰² Finnegan (in prep.), 18. Though sheep provide a better source of meat, milk, and wool, goats would also be an important source of hides in the absence of cows, which are rare at Hauarra.

¹⁰³ Ramsay (in prep.), 45

locally, rather than import it.¹⁰⁴ A cache of beet seeds found at the Roman fort may suggest the presence of a small kitchen garden that grew beets and other vegetables for the soldiers.¹⁰⁵

Even though there is little direct evidence of this type of economic or agricultural activity, on-site production of grain whenever possible still remained the most cost-effective option for supplying the unit's grain requirements. While the soldiers would not likely have been farming the grain themselves, even purchasing their supplies from the local farmers at market price would have resulted in considerable savings over the appended costs of transported grain. If the soldiers were employing the practice of *frumentum emptum*, purchasing the grain at a much-reduced rate, the costs would have been even lower. Further, if the garrison was renting out land under its jurisdiction to civilian tenant farmers in return for a portion of their agricultural produce, they could get their supplies for no cost at all as part of taxation-in-kind. A garrison could not have been installed at Haurra without access to the resources that would help maintain its military presence, and if these resources were available from local sources at much lower costs, then taking advantage of them whenever possible would be the most prudent option.

¹⁰⁴ Ramsay (in prep.), 45

¹⁰⁵ Ramsay (in prep.), 47. Beets are also suited for desert agriculture, and are an efficient food source since both the leaves and roots are edible.

Chapter Four: The Fort at Vindolanda (Chesterholm)

Vindolanda is one of the most famous forts of the northern British frontier, in part due to the recovery of the cache of wooden writing tablets which reveal much about the daily operations of the fort. The fort is located approximately one kilometer south of Hadrian's Wall, and protected the Stanegate road linking the main hubs of Carlisle and Corbridge, which represented the British frontier until the Wall was built starting in 120 A.D.¹. The first five phases of the fort were constructed of timber, even though the local timber was fairly scarce and of poor quality.² The earliest timber fort at Vindolanda dates from roughly 80 A.D., when Agricola consolidated Roman control over Britain and established the northernmost frontier of the Roman Empire.³ The wooden writing tablets from Vindolanda permit a more detailed reconstruction of the garrison's habitation history than is possible at many other auxiliary forts. The theorized chronology of this history is of course subject to constant ongoing revision, but the general trends in occupation still provide useful information regarding garrison strength and the required amounts of supplies that passed through Vindolanda.

Around 90 A.D., the fort was garrisoned by the First Cohort of Tungrians,⁴ for which there is at least one extant strength report among the wooden tablets. This strength report shows that the unit was nominally a double-strength infantry unit, a *cohors peditata milliaria*, information which is borne out by a military diploma of c. 103 A.D.⁵ The unit was reduced to a single strength (*quingenaria*) unit c. 122 A.D., according to another

¹ Birley (1977), 13

² Manning et al. (1997), 184

³ Birley (1977), 12

⁴ Bowman & Thomas (1991), 62

⁵ *CIL* 16.48

diploma, and then re-doubled in 146 A.D.⁶ These changes may perhaps reflect the *ad hoc* adjustments required of frontier garrisons during periods of transition, as the reduction in unit strength corresponds roughly to the building of Hadrian's Wall, and the next increase to the reign of Antoninus Pius and the building of the Antonine Wall in Scotland.⁷ The report lists a strength of 752 men, which is close to the nominal strength of a military cohort; 800 men, at least according to Hyginus.⁸ Interestingly, the first phase of the timber fort at Vindolanda in the period, c. 85 to 92 A.D., would not have been able to hold a *cohors miliaria* like the First Tungrians, which perhaps accounts for the dispatching of 456 soldiers to various other sites nearby, including a sizeable garrison of 337 at Corbridge.⁹ The fort could, however, have easily accommodated the 296 soldiers remaining at Vindolanda. During Phase 2, c. 92-97 A.D., the fort was demolished and enlarged, more than doubling in size, which may have been inspired by the need to house the full *cohors miliaria*.¹⁰

From c. 97-104 A.D., the fort was staffed by a cohort of Batavians, probably the Ninth, although some men from the Third may have been present.¹¹ The writing tablets most heavily represent the records of the Ninth Batavians, although one letter is addressed to a member of the Third.¹² If the enlargement of the fort in Phase 2 had indeed been intended to accommodate the double-strength unit of Tungrians, it would certainly have been large enough to house both cohorts of Batavians, or to house the full Ninth Cohort and a

⁶ *CIL* 16.69-70, *RMD* 97

⁷ Bowman & Thomas (1991), 68

⁸ Bowman & Thomas (1991), 67

⁹ Bowman & Thomas (1991), 68. Such dispersal and fragmentation of frontier units was common.

¹⁰ Manning et. al. (1997), 177

¹¹ Birley (1997), 273

¹² *Tab. Vindol.* 2.311

detachment of the Third.¹³ Auxiliary forts could sometimes house a composite force of two different units; for example, forts at Heddernhein and Echzell in Germany seem to have housed both an *ala* and a cohort, and it seems that the situation of the Batavian units at Vindolanda was similar.¹⁴ The Batavians may have arrived somewhat earlier than initially suggested, but the date of their departure coincides with the onset of the Second Dacian War, suggesting that they were transferred from a potentially less-crucial British outpost to the Dacian frontier to support the armies on the Danube. The fort appears to have been left abandoned rather abruptly, a move consistent with an urgent new posting to the active Dacian campaigns, and to have stood vacant for a time before being haphazardly demolished a few months later.¹⁵ The fort was reconstructed yet again, although the precise date is uncertain, perhaps coinciding with the planning phases of Hadrian's Wall, c. 119-121 A.D., and it appears that the Tungrians returned.¹⁶ The last traces of occupation before the next abandonment phase appears to have been an industrial complex, perhaps concerned with the production of materials for the building crews on Hadrian's Wall.¹⁷

Between 130 and 160 A.D., the fort was abandoned as the garrison moved into their new base at Housesteads, pulling down many of the buildings and removing the timbers as they departed, as was customary for Roman armies abandoning a camp. In 160 A.D., after the abandonment of the Antonine Wall, Vindolanda was reinstated as a frontier fort

¹³ Birley (1994), 88

¹⁴ Davies (2009), 47

¹⁵ Birley (1994), 90

¹⁶ Birley (1994), 108. See also *Tab. Vindol.* 2.295 for a letter addressed to Priscinus, the prefect of the First Tungrians, which dates from this period.

¹⁷ Birley (1994), 124

and rebuilt in stone.¹⁸ The reasons for its recommission are unclear, since the area in which the fort is situated could have been adequately supervised by the existing garrisons at Housesteads, Carrawburgh, and Great Chesters. It may have played a role in the supply system of the frontier, much like Corbridge, or it may have been intended to facilitate the exploitation of the natural resources of lead, iron, and coal in the vicinity.¹⁹

After the fort at Vindolanda was rebuilt in stone, there is evidence that it was garrisoned by the Second and Third Cohorts of Nervians (both single-strength, *quingenaria*), before those were replaced c. 213 A.D. by the part-mounted Fourth Cohort of Gauls, also *quingenaria*, consisting of perhaps 360 infantry and 120 cavalry.²⁰ The size of the fort appears to have been reduced twice in quick succession at this time, resulting in some rebuilding and alterations of the stone structures.²¹ The internal dimensions of the second phase of the stone fort were reduced to the dimensions of the original timber constructions, likely due to the reduced size of the garrison.²²

Granary Structure

The original granaries at Vindolanda were likely timber-built, as was the rest of the original fort. Unfortunately, since the timber fort was disassembled several times before the abandonment phase of 130 A.D., and rebuilt in stone on the same site thirty years later, almost no traces of these older timber structures remain. It is possible, however, to infer what it may have looked like based on better-preserved timber examples from other

¹⁸ Bidwell (1985), 9. Pottery finds seem to confirm an early Hadrianic construction date for the first phase of the stone fort.

¹⁹ Birley (1977), 17

²⁰ Bidwell (1985), 84

²¹ Bidwell (1985), 53

²² Manning et al. (1997), 177. The fort's area is reduced from roughly 7.5 acres to 5.0 acres, and then to 3.5 acres.

sites in Britain. For the most part, these date to the first century of Roman occupation, in keeping with the proliferation of timber forts in this period.

The majority of timber granaries in Britain were constructed on a grid of supporting posts set in evenly-spaced trenches or pits, which both allowed air to ventilate the granary beneath the floor and kept the building clear of both standing water and damp soil. These posts probably lifted the floor about a meter off the ground, as did the floor supports of stone granaries with elevated floors, and they were often left in place at times when the larger timbers of the building were intentionally demolished or removed.²³ These posts, of course, would have to be replaced from time to time as the wood rotted or warped from the moisture in the soil, and at some sites where the building was not completely demolished and rebuilt (for example in the granaries at Richborough), new posts were installed without removing the old posts.²⁴ Though wattle-and-daub construction was used for other timber buildings on Roman military sites, it does not seem that this material was used for the granaries.²⁵ The walls of timber granaries were probably composed of wooden clapboards, likely of oak or some other hardwood, and might have been provisioned with louvered windows to ventilate the inside of the building.²⁶ The roofs were also probably surfaced with wooden shingles, as is seen in the representations of timber buildings on Trajan's Column, as clay roof tiles would be too heavy, and thatch both presented a fire risk and harbored vermin.²⁷ At Vindolanda, however, oak was scarce. The seasoned oak timbers imported specially for the fort appear to have been

²³ Manning (1975a), 106

²⁴ Manning (1975a), 106

²⁵ Manning (1975a), 113

²⁶ Manning (1975a), 113

²⁷ Manning (1975a), 113

reused in multiple phases,²⁸ so the granary was probably constructed of the more common local birch and alder wood, both relatively low-quality timbers. The walls of timber granaries could have been significantly thinner than the walls of stone granaries: perhaps only 0.35 meters thick at most, judging by the cross-sections of surviving timbers, compared to a meter or more for stone granaries.²⁹ This is strange given the force that the grain would exert on the external walls of the building, and may suggest that the grain was stored in sacks or baskets rather than poured loose onto the granary floor or into bins inside. This force no doubt influenced the preference for strong hardwoods like oak in timber granary construction. Timber granaries would have required more maintenance than stone ones, and it is possible that they were regarded as temporary structures, in use until enough stone could be found to replace them.

The grain storage capacities of the timber forts at Vindolanda are as necessarily theoretical as their construction. The original garrison, the First Tungrians, was known to be a *cohors miliaria*, nominally 800-strong. Assuming that this unit was full-strength, and applying Richardson's figures for grain storage (0.5 square meters per man for a yearly supply), the granaries would have needed a maximum internal area of roughly 400 square meters.³⁰ This figure is consistent with the stone granaries of forts which housed *cohortes miliariae*, for example Caernarvon in Wales (internal area of roughly 318 square meters), or Templeborough in South Yorkshire (internal area of roughly 348 square meters).³¹ The timber granaries at Fendoch, with an approximate internal area of roughly 312 square

²⁸ Manning et al. (1997), 184

²⁹ Manning (1975a), 109

³⁰ As with all Roman military units, it was unlikely that the cohort was usually at its full fighting strength.

³¹ Manning (1975a), 119

meters, provide another close parallel to the timber granaries at Vindolanda.³² The fact that Vindolanda could not accommodate the full cohort of Tungrians in the initial phases of its existence may have been due to the fact that the granaries were not large enough to hold the necessary supplies. The increase in the area of the fort seen in Phase 2 would have allowed for a corresponding increase in granary size, which would in turn have accommodated the later garrisons as well.

Excavations in 2008 uncovered the stone granaries of the later fort at Vindolanda to the west of the fort's *principum*. The exact details of these buildings are still to be published, but a few general impressions can be drawn. They are two substantially-constructed stone buildings with buttressed walls, one probably used as a granary proper and the other as a storehouse for other foodstuffs, and they date to the occupation of the Fourth Cohort of Gauls, c. 213 A.D.³³ The granaries were probably badly damaged by fire after the final abandonment of Vindolanda c. 400 A.D.; severely burnt and cracked flagstones in the storehouse building show that it perhaps was used to store olive oil and wine, which would have intensified the flames.³⁴ There is evidence of later habitation in one of the buildings, however, suggesting it was converted to a domestic area in the fifth century A.D.³⁵ The stone granaries also demonstrate the standard arrangements for ventilation and drainage. The flagstone floors were supported by longitudinal sleeper walls running the length of the building, and ventilation shafts crisscross both the sleeper walls and the outer walls of the building to facilitate airflow.³⁶ Longitudinal sleeper walls were the most common method of elevating the floors of stone granaries in Britain, as they seem

³² Gentry (1976), 34

³³ Vindolanda Charitable Trust (2008)

³⁴ Vindolanda Charitable Trust (2008)

³⁵ Vindolanda Charitable Trust (2008)

³⁶ Vindolanda Charitable Trust (2008)

to originate in the Hadrianic period when many forts were converted from timber to stone, and examples from Birrens and Corbridge also demonstrate the method of piercing these sleeper walls with ventilation shafts.³⁷

The official publication will no doubt be more specific, but it can be expected that the internal dimensions of this stone granary furnished sufficient storage space for the cohort of Gauls, which was a part-infantry, part-mounted cohort, and would have needed to store feed for the horses as well. It seems that this area must be contained in only one of the excavated buildings, as it is possible that only one of them was a granary proper, and the other was a general stores building. Given the yearly requirements of the garrison at this time, one could expect the internal area of the granary to cover roughly 240 square meters.

Local Grain Production

Barley appears to have been one of the predominant grains consumed by the garrison at Vindolanda, and barley cultivation in Britain also predates the Roman occupation. Despite the Italian prejudice against barley and the preference to use it as animal feed or as punishment rations,³⁸ barley was frequently consumed as porridge or cakes by the northern European peoples from which the units that garrisoned Vindolanda were recruited.³⁹ The lands around the legionary base at York were already being used for extensive barley and wheat production before the Romans arrived.⁴⁰ It is also possible that the barley was destined for brewing; it is known from references in the wooden writing tablets that beer (*cervesa*) was often consumed at Vindolanda, both by the

³⁷ Gentry (1976), 9

³⁸ *cf.* Plin. *NH* 18.15.75

³⁹ Whittaker (2002), 220

⁴⁰ Whittaker (2002), 225

common soldiers and in the commander's household.⁴¹ Beer would have been an important contribution to the soldier's diet where it was available, perhaps accounting for part of his daily grain ration, and it appears to have been cheaper than wine, at least at Vindolanda. A soldier there purchased roughly 6 *modii* of beer for a price that would have fetched only about an eighth of a *modius* of the cheapest wine.⁴² Another tablet logs a specific request for beer for consumption by the soldiers.⁴³ If the barley was being fed to horses, the amounts quoted in the tablets (between four and a little over six *modii*) would have fed about 12-18 horses for a day.⁴⁴ It is also possible that the cavalry horses were being fed on oats (*avena*), which are attested at sites on Hadrian's Wall during the Roman period.⁴⁵

Another commonly-mentioned grain is *bracis*, a Celtic cereal usually used for beer-brewing, although a reference to threshed *bracis* appears in one letter, suggesting that it was intended for human consumption.⁴⁶ Though it is often identified with emmer, *bracis* is probably more likely a native variant of spelt, which is common in archaeobotanical samples from Britain and other northern provinces.⁴⁷ One tablet offers evidence of a substantial order of spelt wheat (*spica*); 5,000 *modii*, or enough to supply 185 men for one month.⁴⁸ Both barley and spelt are characteristic of pre-Roman cereal farming in Britain, and their predominance at Vindolanda suggests that the Romans continued to support local farming practices.⁴⁹ Emmer wheat is perhaps represented by *alica*, which

⁴¹ *Tab. Vindol.* 2.186, 2.190, 2.482. 2.182 also refers to a brewer, *cervesarius*.

⁴² *Tab. Vindol.* 2.186. 100 *sextarii* of beer for 8 *asses*, which could only pay for about 2-3 *sextarii* of wine.

⁴³ *Tab. Vindol.* 2.505

⁴⁴ Pearce (2002), 938

⁴⁵ *Tab. Vindol.* 2.185

⁴⁶ *Tab. Vindol.* 2.342

⁴⁷ Pearce (2002), 934

⁴⁸ *Tab. Vindol.* 2.342

⁴⁹ Jones (1991), 23

probably refers to the raw, unprocessed emmer grain rather than a prepared foodstuff.⁵⁰ Pliny confuses the issue by referring to it as a sort of porridge made from emmer.⁵¹ There are also references to soldiers collecting moderate quantities of *siligo* (bread wheat) from elsewhere (perhaps grain depots at Corbridge), and this type of grain is typically present in similarly small quantities at other Romano-British sites.⁵² A further 320.5 *modii* of *frumentum* mentioned in another account was portioned out to several men in incremental amounts, perhaps to cover individual rations or collective rations for small groups.⁵³ The garrison clearly had access to a wide variety of cereals and cereal products, and many of these could have been locally produced.

The same anaerobic soil conditions which helped to preserve the Vindolanda Tablets also contributed to the preservation of pollen and seeds that document the plant life of Roman Vindolanda. Pollen evidence suggests that prior to and during the Roman period much of the forest land in the area was cleared, perhaps initially to provide timber for the construction and maintenance of the forts, but also to open up land for animal husbandry, agriculture, and defensive maneuvers.⁵⁴ Cereal pollen is present in soil samples dated to the Roman period, suggesting that the new open spaces were partly used for crop cultivation, but they may have been used primarily for the grazing of animals. The fact that some of the clearance predates the Roman occupation may also imply that the Romans were able to take advantage of land that had already been cleared for farming and grazing, rather than having to initiate the land clearance themselves.⁵⁵ Pollen assemblages dated to the first century A.D. (c. 85-92 A.D.) show that the open land may

⁵⁰ *Tab Vindol.* 2.193, 2.233

⁵¹ *NH* 18.29.112

⁵² Pearce (2002), 934

⁵³ *Tab. Vindol.* 2.180. The cited amounts range from 2 to 26 *modii*.

⁵⁴ Seaward in Van-Driel Murray et al. (1993), 92

⁵⁵ Jones (1991), 25

have been used primarily for pasturage for cattle or sheep, in a continuation of the pre-Roman land use patterns of the area.⁵⁶ In the second century A.D., however, after the frontier had been consolidated at a time when many of the timber forts were being rebuilt in stone, cereal cultivation may have increased, perhaps due to the need for forts on the distant frontier to become self-sufficient, rather than depending on imported supplies as they had earlier.⁵⁷ After 105 A.D., the floors of the buildings in the fort at Vindolanda were laid with straw, rather than the local bracken that had been previously employed. This might suggest that cereals were being grown nearby, since the long-distance importation of something as bulky and relatively cheap as straw would not have been cost-effective, but using the byproduct of grain processing to carpet the floors would have been more practical.⁵⁸ It is very likely that cereals were processed at Vindolanda, as the plant remnants are characteristic of the threshing and filtering of grains for human consumption.⁵⁹ Seed samples recovered from Vindolanda reveal barley (*hordeum vulgare*) all samples of which were charred as would be expected from barley processed for human consumption; spelt wheat (*triticum spelta*) emmer wheat (*triticum dicoccum*) and another wheat strain of indeterminate species.⁶⁰ Bread wheat appears to have been fairly uncommon at northern Romano-British sites, and the samples that reached the northern frontiers must have come from southern Britain, where the growing conditions were more temperate.⁶¹ The granaries at South Shields show that bread wheat was being

⁵⁶ Manning et al. (1997), 184. It has been suggested that the native name for the site, of which “Vindolanda” is the Romanized version, supports the idea of animal pasturage in the area: “white pastures” or “white meadows”.

⁵⁷ Manning et al. (1997), 184. Cereals start to appear c. 100-120 A.D.

⁵⁸ Manning et al. (1997), 184

⁵⁹ Seaward in Van-Driel Murray et al. (1993), 107

⁶⁰ Seaward in Van-Driel Murray et. al. (1993), 107

⁶¹ Whittaker (2002), 222.

imported from Gaul or from southern Britain as late as the third century A.D,⁶² though it is also known that Britain was exporting large quantities of grain to the rest of Europe at this time, so perhaps the supply base at South Shields represents an exchange point of grain, rather than an intake point.⁶³

It has been argued that the northern frontier zones of Britain depended primarily on imports of grain from southern England for their supplies, rather than on local production. Manning has argued quite eloquently against this assumption, showing that the highland zones where the Roman armies were stationed could have produced significantly more crops than had been previously assumed.⁶⁴ While grain may occasionally have been transported from southern Britain, which was more substantially Romanized compared to the frontier zone, the long-term viability of the frontier would have depended on a consistent source of supplies, and the local areas surrounding the forts, which were already producing native spelt and emmer, would have represented the most easily accessible sources. Grain farming in the northern frontier would have been affected by the comparatively cold, damp climate and by the mountainous terrain; but it seems that the ancient climate in Britain as a whole was warmer, drier, and less stormy during the early Roman period, until roughly 250 A.D.⁶⁵ Archaeological evidence and pollen deposits suggest that the Roman period encouraged crop cultivation in northern Britain, as opposed to the predominantly pastoral land use of the pre-Roman era.⁶⁶ Grain farming in the southern areas of Britain might have been more productive, but it is likely that the northern frontier zones were also capable of producing crops, as the pollen

⁶² Whittaker (2002), 226. South Shields was an important supply base at this time, associated with Severus's campaigns into Scotland, so perhaps it was more heavily stocked than other forts on the northern frontier.

⁶³ Manning (1975b), 116

⁶⁴ 1975b

⁶⁵ Jones (1996), 204

⁶⁶ Jones (1996), 205

evidence found at Vindolanda would seem to suggest. Cultivation marks from agricultural fields have also been discovered beneath Hadrian's Wall, showing that the highland zone wherein the military established itself was already under cultivation before the wall was built.⁶⁷

The grain yields and amount of arable land required to feed the army have been the subject of a number of theoretical calculations. Estimates for the military presence in Britain range from a minimum of 40,000 men to a maximum of 63,000, with a typically-accepted average of 50,000.⁶⁸ Iron Age grain yields (probably in the more agriculturally-established south) ranged from 1.25 to 2.25 metric tons per hectare,⁶⁹ and the modern-day Iron Age experimental farm at Butser Farm in southwest England has produced average yields of 2 metric tons per hectare.⁷⁰ More conservative estimates of Roman-era grain production, however, offer 0.7 metric tons per hectare, or as little as 0.35 metric tons per hectare, both of which would seem more likely than the Butser Farm yields in an agriculturally marginal area such as the highland zone of northern Britain.⁷¹ Comparative evidence from eighteenth century Wales (part of the same highland zone as the region of Hadrian's Wall, and noted by contemporary writers for its agricultural marginality), however, suggest average yields of 0.9 metric tons per hectare.⁷²

At yields of 0.7 metric tons per hectare, supplying the yearly grain requirements of a single cohort of roughly 480 men (the usual garrison of a fort on the Wall), or roughly 197 metric tons of grain, would have required roughly 281 hectares of arable land. At yields of 0.35 metric tons per hectare, this number rises to roughly 562 hectares, and at

⁶⁷ Jones (1991), 25

⁶⁸ Jones (1996), 209

⁶⁹ Hyland (1990), 93

⁷⁰ Jones (1996), 211

⁷¹ Jones (1996), 209

⁷² Manning (1975b), 112

yields of 0.9 metric tons per hectare, it drops to roughly 218 hectares. According to these figures, supplying the garrison at Vindolanda, which was at most 800-strong and at least 480-strong, would have required roughly between 218 hectares (480 men at yields of 0.9 metric tons per hectare) and 938 hectares (800 men at yields of 0.35 metric tons per hectare) of arable land, depending on the average yields of grain. The garrison would also have had to consider the grain fodder for its horses; the Ninth Batavians and the Fourth Gauls were both *cohortes quingenariae equitatae*, having roughly 132 horses to feed.⁷³ Each of these horses would require roughly 1,080 kg of feed per year, for a total of 142 metric tons per cohort to feed their mounts. Though the presence of cattle ranching in the area in antiquity attests to the presence of significant grazing, the garrison at Vindolanda might also have had to provide grain fodder for its pack animals. This amount could have been significantly reduced by turning the animals out to graze, but it is impossible to determine how often the animals were pastured, or by what factor this would reduce the need for grain fodder. It is also unknown whether these pack animals were mules, or local ponies, but the figures for mules will be used, assuming a full complement and full grain rations in order to determine the maximum requirements. A double-strength cohort would have had a full complement of 320 mules, requiring 233 metric tons of grain fodder each year, and a single-strength cohort 160 mules, requiring annual supplies of 116 metric tons.⁷⁴ The total grain requirements for the animals in the garrison at Vindolanda would therefore total a minimum of 142 metric tons per year (if a single-strength garrison fed its horses on grain fodder and turned the pack animals out to graze) and a maximum of 375 metric tons per year (if a double-strength garrison was feeding both its horses and its

⁷³ Holder (1980), 216, 221

⁷⁴ See above, pp. 42

pack animals on full rations of grain fodder). Assuming that the grains that were grown for fodder (most likely oats or barley) yielded at roughly the same rate as the grain grown for the men, this would add a minimum of 157 hectares (at yields of 0.9 metric tons per hectare), for a minimum total area of 375 hectares; and a maximum of 1,071 hectares (at yields of 0.35 metric tons per hectare), for a total maximum area of 2,009 hectares. These land totals fall well within the sizes of theorized legionary *territoria* in Britain (roughly 50 square kilometers at Colchester, and as much as 500 square kilometers at Gloucester and Lincoln⁷⁵), and indeed auxiliary *territoria* were likely to be smaller than legionary. The heavy garrisoning of Hadrian's Wall may have negatively impacted the ability of an individual garrison to draw on as much land as it needed, since forts in this area were often ten kilometers or less apart, as opposed to the 16 or so kilometers typically observed for in-depth garrisoning,⁷⁶ but it also assured that a supplementary source of grain was nearby in the form of a neighboring fort. Nevertheless, Housesteads, a short distance north of Vindolanda, in a comparatively rougher area demonstrates evidence of a plowed field system near the fort itself.⁷⁷

The closest local source of grain to Vindolanda was most likely the South Tyne valley, some two to three kilometers to the southwest of Vindolanda, where the alluvial deposits of the South Tyne floodplain could have supported good supplies of grain.⁷⁸ Indeed, most of the forts along the line of Hadrian's Wall had similar alluvial valleys nearby, situating them near the most profitable agricultural areas in the region.⁷⁹ The South Tyne valley itself represents roughly 120 square kilometers (some 12,000 hectares) of arable land, the

⁷⁵ Mason (1988), 169-170

⁷⁶ Manning (1975b), 115

⁷⁷ Manning (1975b), 116

⁷⁸ Birley (1997), 276

⁷⁹ See Birley (1977), 14-15 for a map of Wall forts with relative positions of river valleys; the Eden and Irthing rivers on the western side of the country, the South Tyne in the middle, and the Tyne proper in the east.

sheltered, milder climate and favorable soil of which still fosters agriculture today, and must have been even more valuable to the Roman garrisons of the area in antiquity.⁸⁰ Of course, the grain requirements of the civilian population must be taken into account as well. Estimating the civilian population at Vindolanda is difficult, as it is at any military *vicus*. Based on the excavated parts of the *vicus* at Vindolanda and on theoretical calculations of marriage rates drawn from military diplomas, Birley has estimated that the civilian population of Vindolanda to have ranged between 500 people in 163 A.D., and as many as 1,500 people in 350 A.D.⁸¹ Sommer, however, suggests that these figures are at least twice as high as they should be, and the population of the standard military *vicus* was never much higher than the population of the garrison.⁸² He compares the *vicus* at Vindolanda with the *vicus* at Zugmantel in Germany, where approximately 80 excavated houses inhabited by four to five people per house would yield a total population of between 320 and 400 people, a few less than the auxiliary cohort stationed there.⁸³ If these more conservative estimates hold true for Vindolanda, where the garrison was a single cohort in both 163 A.D. and 350 A.D., the civilian population of the *vicus* might have been at most 500 people.

If the civilians at Vindolanda were consuming grain at a rate of roughly 0.8 kg per day,⁸⁴ they would require roughly 146 metric tons per year. This would in turn require the produce of a minimum of 162 hectares (at yields of 0.9 metric tons per hectare) and a maximum of 417 hectares (at yields of 0.35 metric tons per hectare), in addition to the land area needed to sustain the garrison. The strength of the garrison combined with the

⁸⁰ Sykes (1933), 273

⁸¹ Birley (1977), 72

⁸² Sommer (1984), 33

⁸³ Sommer (1984), 108

⁸⁴ Foxhall & Forbes (1982), 51

civilian population of this period, would have required a minimum of 538 hectares (at yields of 0.9 metric tons per hectare) and a maximum of 2,051 hectares of land (at yields of 0.35 metric tons per hectare) to furnish the necessary grain crops. Loss rates of fourteen percent and seed grain (assuming the standard sowing rates recommended by Pliny for “thick, or chalky, or wet soil” of six *modii* per *iugerum*, or roughly 216 kg per hectare⁸⁵) would account for roughly an additional 204 hectares minimum, for a total of 742 hectares; and 1,552 hectares maximum, for a total of 3,603 hectares. Such areas of agricultural land are still within the realm of possibility in the region.

External Sources of Grain

The tablets from Vindolanda also contain mentions of cartage of supplies, often carried out by civilian convoys. For example, “the wagons of the Britons” (*carris Brittonum*) are mentioned in connection with the transportation of supplies, mainly of grain.⁸⁶ Octavius and Candidus, the two men concerned with the shipment of 5,000 *modii* of wheat, who seem to be engaged in wagon cartage, were probably civilian contractors supplying the fort with goods.⁸⁷ Some very fragmentary tablets also make reference to the unloading of wagonloads of barley over a period of days.⁸⁸ It is not clear to whom these wagons belong, but it seems that the wagon drivers (called *bubulcarii* in the tablets) kept their oxen nearby at Vindolanda, and received rations of grain, which suggests that they may have been official commissary personnel.⁸⁹ Although though the wagons may have originated elsewhere, it seems that they were assigned to the service of the commissary at

⁸⁵ *NH* 18.55.199. Both Varro (*Rust.* 1.44.1) and Columella (*Rust.* 2.9.1) recommend five *modii* per *iugerum* for “medium-quality” land, which is less specific than Pliny’s description.

⁸⁶ *Tab. Vindol.* Inv. 91/1108

⁸⁷ *Tab. Vindol.* 2.343.

⁸⁸ Birley (1997), 276

⁸⁹ *Tab. Vindol.* 2.180, where these *bubulcarii* are staying “in the woods” and receive *frumentum*.

Vindolanda; one letter involves the fort prefect dispatching wagons to cart goods, and another refers to spare parts needed for wagon repair.⁹⁰ The grain depots at Corbridge were only 24 kilometers east of Vindolanda, so frequent trips between the two forts would have been relatively quick, though the Octavius/Candidus letter does refer to harm that might come to the animals on bad roads.⁹¹ A fragmentary pair of lists among the tablets mention frequent collection of small quantities of *siligo* (perhaps by the soldiers themselves) at a time when this type of wheat would not yet have been ready to harvest, suggesting that these reserves were drawn from the stored produce of the previous year.⁹²

Importation of grain from elsewhere in Britain may have been accomplished by sea, though there is little evidence that this was on a large-scale or a regular occurrence.⁹³ This sort of maritime importation would have lessened transport costs somewhat, but overland transport in wagons would still have to be employed, and, according to the tablets, it seems to have been the preferred option for overland transport in the area. Indeed, transport seems to have been exclusively by wagon; there is no archaeological evidence in the written tablets or elsewhere for transport along the Tyne and South Tyne rivers, despite their proximity to the fort itself.⁹⁴ The North Sea coast, with ports at South Shields and Wallsend, was roughly 60 km from Vindolanda, and the Atlantic coast of Solway Firth, with ports at Bowness and Drumburgh was roughly 55 km away, situating Vindolanda at almost the center of the transport route between the two seas. The Stanegate road would provide relatively reliable cart or wagon transportation (at least

⁹⁰ *Tab. Vindol. Inv. 85/103, Inv. 85/51*

⁹¹ Birley (1997), 276, *Tab. Vindol. 2.342*, perhaps in icy or slick conditions, as the letter was probably written sometime between January and March.

⁹² *Tab. Vindol. Inv. 93/1495*.

⁹³ Manning (1975b), 116

⁹⁴ Anderson (1992), 43. Though there is also no evidence against river transport for a portion of the journey and wagon transport for the remainder.

between Carlisle and Corbridge, and perhaps as far as South Shields), so it would make sense to transport the grain in wagons, though baggage trains of pack ponies are not out of the question. In the *Edict on Maximum Prices*, a wagonload is defined as 60 *modii*, or roughly 540 kilograms, and this is close to the average capacity of the wagons used in North Africa in the service of the *cursus clabularius*.⁹⁵ It would take between 287 (for the single-strength garrison) and 574 (for the double-strength garrison) loads of this size to cart the entirety of Vindolanda's annual grain supply, and each of these would be subject to the 12 *denarii*-per-kilometer transport surcharge. Transporting the grain from the North Sea coast would incur a theoretical maximum 720 *denarii* of transport costs per wagon, and transport from the Atlantic coast would incur a theoretical maximum charge of 660 *denarii* per wagon. If the garrison imported the entirety of their grain supplies, they could expect to incur additional transport costs on top of the purchase price of the grain: a minimum of roughly 189,000 *denarii* for import of a single-strength cohort's supply from the Atlantic coast, and a maximum of roughly 413,000 *denarii* for import of a double-strength cohort's supply from the North Sea coast. Again, it is possible that the garrison imported some supplies of grain, in bad years, or in the early days of the garrison before local production was stimulated, but it is impossible to tell in what proportions. What is clear, however, is the cost of transporting supplies to Vindolanda overland would have motivated the garrison to seek local supplies whenever possible.

Although grain represented perhaps the highest volume of food obtained from the surrounding area, it was not the only local foodstuff to which the garrison at Vindolanda had access. Archaeological evidence suggests that the soldiers kept their own pigs,

⁹⁵ Rickman (1980b), 264. Compare the 540-kg official load with an average capacity of roughly 560 kg for the North African wagons.

chickens and geese for meat, as well as keeping sheep and goats for their wool and milk.⁹⁶ Celtic shorthorn cattle, perhaps purchased from local ranchers, would have supplied the soldiers with both beef and hides, and probably with milk as well.⁹⁷ The commander of the Ninth Batavians, Flavius Cerialis, also seems to have occasionally hunted game, judging by a request for hunting-nets in one of his letters.⁹⁸ The bones of several types of deer have been recovered from Vindolanda, in much greater numbers than at other sites in the region, and it appears that venison was sometimes issued to soldiers as part of their rations.⁹⁹ Wild birds also appear to have been a source of meat, according to references to nets for catching thrushes and ducks and lassos for catching swans.¹⁰⁰ Large numbers of oyster shells have also been found, and Vindolanda's relative proximity to the North Sea coast would have facilitated procurement of such marine shellfish.¹⁰¹ One letter among the Vindolanda tablets refers to purchasing eggs, beans, chickens, and apples, all of which were likely local produce, as well as imported delicacies such as *mulsum* (honeyed wine), *muria* (low-quality fish sauce), and olives.¹⁰²

It is clear that Vindolanda had access to a variety of local foodstuffs, one of which was almost certainly grain. No direct evidence of grain cultivation has yet been found at Vindolanda, but evidence of a plowed field system at Housesteads, only a short distance to the north, suggests that similar farming could have taken place at other forts in the area. Evidence of plow furrows from the fortress at Usk in Wales places cultivation

⁹⁶ *Tab. Vindol.* 2.183 for pigs, Inv. 93/1474 for poultry.

⁹⁷ Seaward in Van-Driel Murray et al. (1993), 110

⁹⁸ *Tab. Vindol.* 2.233

⁹⁹ Seaward in Van-Driel Murray et al. (1993), 112

¹⁰⁰ *Tab. Vindol.* Inv. 93/1462

¹⁰¹ Seaward in Van-Driel Murray et al. (1993), 114

¹⁰² *Tab. Vindol.* 2.302

around forts even earlier, to the reign of Nero.¹⁰³ It could hardly have been an accident that the positioning of Hadrian's Wall along the various river valleys of the Pennines situated the garrisons near the best farming land in the area. Though importation may have been required for the early phases of the fort, the costs of transportation and purchase could be significantly reduced by encouraging local production. Ultimately, Hadrian's Wall and the northern frontier of Britain would not have been sustainable without sufficient supplies, and the local area was more capable of producing them than has been previously thought.

¹⁰³ Manning (1975b), 115

Chapter Five: The Fort at Vindonissa (Windisch)

The fortress at Vindonissa served as home to three legions over the course of its life. It was one of the earliest fortifications to be established in Germany, and it became an important point of control for the German frontier. Vindonissa was the only legionary base in northern Switzerland, responsible for maintaining control over the area, and eventually, along with Mainz and Strasbourg, it became one of the three major legionary forts in the province of Germania Superior.¹ Like many forts in northern Europe, it was first built in timber c. 16 A.D.², positioned at the junction of both the Aare and Reuss rivers, and two major roads: the east-west road between Augusta Raurica and Pannonia, and the north-south road across the Jura pass. This site made Vindonissa of primary strategic importance to communications and traffic moving along the German frontiers. The first garrison of the fort, in its early timber phase, was probably the Legio XIII Gemina, which was transferred to Pannonia c. 46 A.D.³ The XIII Gemina was replaced by the Legio XXI Rapax, whose soldiers probably constructed the stone fort as it is visible today, and which was transferred to Bonn following the civil conflicts of 69 A.D.⁴ The final legionary garrison of the fort appears to have been the Legio XI Claudia Pia Fidelis, which abandoned the fort c. 101 A.D.⁵ The annexation of the *agri decumantes* and the consolidation of the Rhine frontier under Trajan reduced the tactical necessity of Vindonissa, and when the XI Claudia was transferred to its new base at Brigetio on the Danube to support Trajan's campaigns in Dacia, the fort was generally abandoned.

¹ Schönberger (1969), 160

² Baatz (2002), 151

³ Schönberger (1969), 153

⁴ Schönberger (1969), 155

⁵ Baatz (2000), 151

Diocletian's construction of a new legionary fortress at Kaiseraugst removed Vindonissa's tactical importance for good, and although the Romans fought and won an important battle against the Alemanni nearby in 298 A.D., Vindonissa did not regain its former status as a tactical linchpin of the German frontier.⁶

Granary Structure

The earliest timber phase of the fort at Vindonissa naturally had a timber granary. The floors of this granary were carried on timber posts set into longitudinal sleeper trenches, paralleling the wooden granaries at Richborough and Fishbourne in Britain.⁷ Supporting the floor in this way seems to have been rare in Germany, where the posts were more commonly driven into their own individual holes, such as at Haltern, Hofheim, and Saalburg, rather than into trenches.⁸ Vindonissa's timber granary measured approximately 19 meters wide by 43 meters long, and in general German *horrea* were wider and larger in area than British *horrea*.⁹ The ratio of length to width in German *horrea* is roughly two to one, as opposed to the ratio of roughly three to one seen in British *horrea*.¹⁰ The timber granary could therefore have held a year's supplies for roughly 1,635 infantrymen, perhaps a bit more than a third of a legion.¹¹

A granary was built of stone at Vindonissa during the reconstruction of the fortress c. 45 A.D. In general the stone-built granaries of German forts are more difficult to categorize than British granaries, and the German examples demonstrate a variety of flexible constructions. This may be attributed to the long occupation history of the

⁶ Schönberger (1969), 179

⁷ Rickman (1971), 239

⁸ Rickman (1971), 239

⁹ Rickman (1971), 239

¹⁰ Rickman (1971), 247

¹¹ According to a legion size of 5,280 men, see Roth (1994), 362

German frontier, which was both hotly contested and continuously consolidated and reorganized by a series of emperors from the late first century B.C. to the late first century A.D. This history must have introduced more flexibility into the construction and reconstruction of forts in Germany as compared to forts in Britain where the frontier and stone forts were consolidated over a relatively short stretch of time in the second century A.D.

The floor of Vindonissa's stone granary was supported by dwarf pillars, which was a common method for elevating the floor among German stone granaries, in contrast to the transverse and longitudinal sleeper walls commonly used in the stone granaries of Britain.¹² Carrying the floor on pillars perhaps allowed for the freer circulation of air beneath the floor, as opposed to the sleeper walls of Britain, which had to be punctuated by gaps in order to circulate the air between the walls. The stone granaries at Hüfingen and Neuss also use this method of floor support, but their pillars are stone, whereas the pillars at Vindonissa are brick.¹³ The presence of "calcareous soil" within the stone granary at Vindonissa may be the remnants of plaster that covered the walls and floor.¹⁴ The granary also has no buttresses, which were a regular feature of Roman stone granaries, and the absence of this feature may suggest that the granary was half-timbered; built mainly from timber on a short stone foundation wall, rather than built completely of stone.¹⁵

The stone fort at Vindonissa is unusual in that only one building has yet been firmly identified as a granary. Based on other legionary forts of similar size, there should be at

¹² Rickman (1971), 241

¹³ Laur-Belart (1935), 56

¹⁴ Laur-Belart (1935), 56

¹⁵ Johnson (1983), 149

least two granaries, and perhaps more; Chester in Britain, for example, has three, and Inchtuthil in Scotland has what is presumed to be a full set of six.¹⁶ It is possible that other granaries at Vindonissa have not yet been excavated, but nevertheless, the isolation of this one granary near the gate without any other possible granary buildings nearby would be unconventional. The granaries at Inchtuthil are distributed to each of the quadrants of the fortress: two near the northern gate, one at the southern gate, two behind the *praetorium* in the northwestern quadrant, and one near the hospital in the northeastern quadrant. If the granaries at Vindonissa were similarly scattered throughout the fort as were the granaries at Inchtuthil, it seems reasonable to believe that there are other granaries at Vindonissa yet to be discovered.

The oddly-shaped layout of the fort itself may have influenced the distribution of the granaries at Vindonissa: the irregular heptagon shape of the fort was influenced by the contours of the land itself, a feature of early imperial forts.¹⁷ During the reign of Claudius, however, stone forts begin to take on the characteristic “playing-card” shape, and Vindonissa is an anomaly in this respect. The stone fort at Vindonissa, therefore, might either have preserved the arrangement of the first timber fort, which was established during the reign of Tiberius, or else adapted organically by annexing land into the defenses of the fort during the stone reconstruction. German stone granaries are typically single buildings, rather than the common form of side-by-side paired buildings seen at other sites, for example at Caerhun and Hardknott in Britain. The building at Vindonissa is positioned just inside the north gate of the fort, as was common with the

¹⁶ Shirley (2001), 57

¹⁷ Johnson (1983), 234

granaries in legionary fortresses as opposed to near the *principum* as in auxiliary forts.¹⁸

This siting seems to be focused on nearby avenues of water transport: at Chester, all three granaries are positioned near the western gate, which led to the river.¹⁹ Vindonissa's granary is similarly sited; the Aare River runs just outside the northern gate of the fortress.²⁰

The stone granary at Vindonissa measures roughly 34 meters long by 11 meters wide, slightly smaller than the timber granary of the previous phase of the fort.²¹ These dimensions would yield an internal floor area of roughly 374 square meters, which, according to Richardson's capacity calculations, would only hold enough grain to supply roughly 750 men for a year. If this were the only granary, it would mean that the legion was in constant need of resupply, and vulnerable to siege or to any other incident which might damage its supply lines. The timber granaries at Inchtuthil, by contrast, measured roughly 42 meters long by 12 meters wide, giving an internal area for each granary of roughly 504 square meters. Six of these granaries would contain roughly 3,024 square meters of floor area, or enough space to store an annual supply of grain for 6,050 infantrymen, more than the nominal strength of an imperial legion. It also seems that space was left within the outer defenses of Inchtuthil for the construction of two more granaries,²² which, if they had been built to the same specifications as the already extant granaries, would have boosted the total granary capacity to annual supplies for roughly 8,065 infantrymen. If there are other granaries at Vindonissa, and if these granaries were built to the same specifications that govern the granary already uncovered, the legion

¹⁸ Rickman (1971), 235

¹⁹ Rickman (1971), 235

²⁰ Laur-Belart (1935), 56

²¹ Laur-Belart (1935), 56

²² Shirley (2001), 57

would require at least seven more of them to store its annual provisions. This would fit neatly with the parallel evidence from Inchtuthil, where there were likely intended to be eight granaries all of similar dimensions spread throughout the fort. This scattered distribution of granary buildings around the interior of the fort would be both tactically and practically prudent; it would eliminate the possibility that a garrison's grain supply could be completely destroyed by a concentrated enemy strike, and it would also alleviate congestion in one particular area during the distribution of rations. Given the stated strength of Vindonissa's garrison, there is sufficient evidence to believe that there are other structures yet to be discovered.

Though only one building within the fort corresponds to the standards of Roman military *horrea*, there is another building at Vindonissa which may have functioned as a storage building. It dates to the stone reconstruction of the fort, and is supposed to have been some kind of storehouse.²³ The building, consisting of a series of small, square rooms roughly 5.2 meters by 5.8 meters, all opening onto a central courtyard, is situated in the southeastern quadrant of the fort, near the south gate. While the layout of this building is has almost nothing in common with other examples of military granaries, it is very similar to the layouts of the large civilian *horrea* at Ostia and Rome.²⁴ The walls of the building are of a similar thickness to the walls of stone-built granaries, roughly 1.2 meters,²⁵ and the depth of the building's foundations as well as the presence of potential staircases seem to suggest that it was two stories tall, which could also have been the case with some granaries.²⁶

²³ Rickman (1971), 259

²⁴ Rickman (1971), 4

²⁵ Rickman (1971), 259

²⁶ Richardson (2004), 436

Similar courtyard buildings have been found at Carnuntum, Lambaesis in North Africa, and Bonn in southwestern Germany, all of which were legionary fortresses, and an unfinished example has also been discovered at Corbridge in Britain.²⁷ Rickman has suggested that these buildings were baggage buildings, used for storing the supplementary gear that the legion did not immediately need, and also that the army helped this type of structure to proliferate through the empire as a civilian store building.²⁸ If this was the case, though, it would seem odd that this type of building is found primarily in legionary fortresses and not often found in auxiliary fortresses (with the possible exception of Corbridge), since the auxiliary units—many of whom were cavalry units—would have gear as well, and would have needed to store it when it was not being used. It is possible that food supplies and perhaps grain were stored in the courtyard building as well, as they were in the civilian *horrea*.

An example of this type of building from Karanis in Egypt, dating to roughly the first century A.D., seems to have been used solely as a granary, even though most of the construction considerations for temperature control and ventilation demanded by grain storage do not seem to be present in this type of building.²⁹ The courtyard building at Vindonissa does have a drain around the interior of the courtyard which drains water away from the inside of the building, possibly an attempt to keep the contents of the building's rooms dry in the absence of elevated floors. Containing the grain in sacks or baskets may have ameliorated the force that the grain would exert on the building itself; and it is possible that provisions for ventilation could be done away with, as in some

²⁷ Rickman (1971), 261

²⁸ Rickman (1971), 263

²⁹ Rickman (1971), 263

stone-built *horrea*,³⁰ though this does beg the question of why the floor of the already-identified granary at Vindonissa is elevated on posts while the floor of this building is not. The building at Vindonissa was probably not one of the major grain storage buildings of the fort, as it would be counterintuitive to store exclusively grain in a building such as this when typical military *horrea* specifically designed for grain storage were available, but the courtyard building could perhaps function as a temporary or overflow storage until the grain could be transferred into the main granaries. It is also possible that the granaries at Vindonissa were reserved explicitly for grain, rather than also serving as a cold-storage for both grain and other foods, and that the other food products that the garrison required, such as fruit, meat, and vegetables, were stored in this courtyard building.

Local Grain Production

Archaeobotanical evidence taken from Vindonissa and dating from roughly 10 B.C. to 15 A.D. demonstrates the presence of grain on the site. Both cereal grains and cereal chaff are represented, indicating that grain was processed at Vindonissa during the Roman occupation,³¹ and also that cereal agriculture was being practiced in the region prior to the establishment of the fort itself. Barley, emmer, and spelt all appear in the samples (a mix similar to that found at sites in Roman Britain), and interestingly, both broomcorn millet (*panicum miliaceum*) and foxtail millet (*setaria italica*) greatly outnumber the traditional cereal crops.³² Millets in the Roman period are most common in civilian *vici* of the region, the settlements outside forts, as opposed to within the forts

³⁰ Johnson (1983), 149

³¹ Jacomet et al. (2002), 82

³² Jacomet et al. (2002), 82

themselves.³³ It seems, based on this evidence, that the local civilians ate millet more regularly than the soldiers did, which may in turn indicate a division of crop requirements; the Roman soldiers ate spelt wheat or bread wheat, and the civilians ate millet. Archaeobotanical studies of other sites in northern Switzerland show that in the Roman period, spelt and millets were the predominant crops of the area, in contrast to the upper Rhine valley where predominantly bread wheat (*triticum aestivum*) was grown.³⁴ Spelt wheat also dominates crop assemblages from Roman *villae* in Switzerland, showing that this crop was probably the one most suited to the agricultural conditions of Switzerland, in contrast to the Rhine valley further north, where bread wheat could be grown.³⁵ This also contrasts cereal agriculture at native German sites outside the boundaries of the Roman Empire, where einkorn (*triticum monococcum*), barley, and rye (*secale cereale*) are the predominant grain crops.³⁶ The crop assemblages from the Roman period indicate organized mass production of grain, rather than the smaller subsistence farming of the native German communities.³⁷ With the army present as a source of ongoing demand, this type of mass production probably helped the farms in the Roman-controlled area provide a surplus of grain.

Tiles bearing legionary stamps have been found at several sites surrounding Vindonissa, including several civilian farmsteads. The presence of these tiles has been taken as an indication of the extent of the fort's *territorium*; the army garrison helped to develop local agriculture by fostering the development of these farmsteads and providing official building materials (possibly produced in the fort's own factories) to construct

³³ Rösch et al. (1992), 227

³⁴ Rösch et al. (1992), 206

³⁵ Rösch et al. (1992), 206

³⁶ Rösch et al. (1992), 209

³⁷ Rösch et al. (1992), 209

them.³⁸ The army could then depend on these local farmsteads to provide food to the garrison, thereby reducing the need to depend on external supplies. The presence of tiles, however, while a useful tool in estimating the area of influence each legion might have commanded, can also be misleading, as it is possible that these tiles were transported over long distances to other fortifications and buildings outside the *territorium* of the legion itself, or otherwise displaced after the abandonment of the buildings. At Xanten in northwestern Germany, for example, the farms at which legionary tiles have been found are restricted to a clearly defined area of roughly 35 square kilometers.³⁹ Compared to other legionary *territoria*, this would seem rather small, and so perhaps Xanten commanded more land than the distribution of its tiles might suggest. The distribution of Vindonissa's tiles would seem to indicate a *territorium* of roughly 1,350 square kilometers, a truly enormous stretch of land, and if similar parameters based on distributions of stamped tiles were applied to other legionary fortresses, for example to Chester in Britain, the resulting area of land would cover more than 5,500 square kilometers.⁴⁰ This is clearly not practical, especially in an area where garrisoning was so dense. It seems that for fortresses on the Rhine and Danube frontiers, more modest estimates of *territorium* size are possible. At Carnuntum on the Danube, the minimum area of the legion's *territorium* seems to be roughly 420 square kilometers, more in line with the areas of legionary *territoria* in Britain, at Lincoln, Chester, and Caerleon.⁴¹ Based on this, it seems more reasonable to peg the extent of Vindonissa's *territorium* at

³⁸ Mason (1988), 166

³⁹ Mason (1988), 166

⁴⁰ Mason (1988), 166

⁴¹ Mason (1988), 168

roughly 450 square kilometers, similar in dimension to the *territoria* of other legionary installments.

Roman-period grain yields in Switzerland and the rest of northwestern Europe are difficult to estimate, as they are throughout the Roman world. Prior to the development of modern farming techniques in the eighteenth and nineteenth centuries, yields in northwestern and central Europe must have been low, and medieval written sources suggest yields of between three-to-one and four-to-one, depending on regional variation.⁴² Even in the later eighteenth century, grain yields in Germany were on average a modest five-to-one, at a time when yields in England and Holland were as high as eight- or ten-to-one.⁴³ Yields of three- or four-to-one would seem to coincide with Columella's description of wheat productivity,⁴⁴ though he ascribes this figure to Italy, where Medieval grain yields usually averaged five to one.⁴⁵ The colder climatic conditions and heavier clay soils of Europe would also have impacted grain production in the Roman period, because the germination rate for seeds is lower in heavy, cold soil, leading in turn to lower yields.⁴⁶ In northern Britain, for example, yields for the Roman period could range between 1.5-to-one and four-to-one.⁴⁷ Given the comparative evidence, and accepting that farming techniques in the Medieval period were not drastically different from those in the Roman period (as opposed to more modern farming), it seems likely that a conservative estimate for yields in Switzerland during the Roman period is on average between three-to-one and four-to-one. Applying Pliny's recommended sowing rates for heavy, wet soil, namely six *modii* per *iugerum*, or roughly

⁴² Gent & Dark (2001), 61

⁴³ Erdkamp (2005), 38

⁴⁴ *Rust.* 3.3.4

⁴⁵ Gent & Dark (2001), 61

⁴⁶ Erdkamp (2005), 39

⁴⁷ See Chapter Four.

216 kg per hectare,⁴⁸ these types of yields would result in production of roughly 650 kg to 865 kg per hectare.

As a legionary base, Vindonissa's grain requirements would have been much larger than those of an auxiliary fort. The nominal strength of a legion was roughly 5,280 men,⁴⁹ and it is also possible that at least one auxiliary cohort was stationed at Vindonissa contemporaneously with the legions. Tile stamps found at Vindonissa, while most commonly marked with the names of the legionary garrisons, also show the designations of some auxiliary cohorts: the Sixth and Seventh Raetians, the Third Spaniards, and the Twenty-Sixth Volunteers.⁵⁰ The sharing of a fort between a legion and one of more auxiliary cohorts appears to have been a common practice until roughly the mid-first century A.D., until the auxiliary units were generally moved to their bases on the frontiers, though still operating under the jurisdiction of the legion.⁵¹ The occupation history of auxiliary units at Vindonissa is difficult to date; most of the auxiliary cohorts present seem to be stationed there during the first century A.D, between the reigns of Tiberius and Vespasian.⁵² This would coincide with the trend of stationing legions and auxiliary units together until the mid-first century A.D. The two cohorts of Raetians would also have been native units, and perhaps this influenced the decision to station them at Vindonissa. The addition of these cohorts would add a minimum of 480 extra men to feed (if only one cohort was stationed with the legion at a time) and a maximum of 1,920 extra men (if all four cohorts were stationed there concurrently). The total garrison strength, therefore, was likely between 5,760 and 7,200 soldiers. The annual

⁴⁸ *NH* 18.55.199

⁴⁹ Roth (1994), 362

⁵⁰ Laur-Belart (1935), Fig. 37

⁵¹ Johnson (1983), 19

⁵² Holder (1980), 322

grain requirements for the men of the garrison would therefore be a minimum of roughly 2,365 metric tons and a maximum of roughly 2,956 metric tons. The legion would also have had a detachment of mounted troops as well, and so would have needed to feed the cavalry horses. All of the auxiliary cohorts that may have been stationed at Vindonissa appear to have been infantry cohorts,⁵³ so provisions would only have to be furnished for the legion's horses, 328 mounts. At an annual consumption rate of 1,080 kg per horse per year, these horses would consume an additional 354 metric tons of grain a year. If the legion was keeping its full complement of 1,060 mules, their grain requirements would have been roughly 773 metric tons per year, and the pack animals of the auxiliary cohorts would have accounted for a maximum of another roughly 467 metric tons, if there were four cohorts on site all feeding their full complements of 160 mules a full grain ration.⁵⁴ The need for fodder for the pack animals, of course, may have been significantly reduced given the likely presence of sufficient pastureland where the animals could graze. The total military demand on grain reserves would therefore be between 2,719 metric tons (if the garrison was feeding the cavalry horses, but not the mules) and 4,550 metric tons (if they were feeding both the horses and the maximum potential number of mules) per year.

For the civilian population, the calculations are of course even more speculative. The amphitheater at Vindonissa, probably the most helpful structure for calculating the civilian population in the absence of domestic houses, could have seated roughly 10,000 people.⁵⁵ The amphitheater at Chester, by comparison, where there was also a legionary fortress, could seat roughly the same amount.⁵⁶ While it is unlikely that the entire military

⁵³ Holder (1980), 224, 235, 238

⁵⁴ See above, pp. 42

⁵⁵ Laur-Belart (1935), 72

⁵⁶ Mason (1987), 151

population would be in attendance at the amphitheater at once, it is still clear that both structures, at Vindonissa and at Chester, could have comfortably accommodated the whole garrison with space left for civilian attendees. Assuming roughly the same ratio of soldiers to civilians seen in other settlements, that is roughly the same number of civilians as soldiers,⁵⁷ the civilian population at Vindonissa can be estimated at around 6,000 people. Assuming further that these people were consuming roughly 0.8 kg of grain per day, the civilians of Vindonissa would have required roughly 1,750 metric tons of grain per year. Altogether, the yearly grain requirements for the soldiers and civilians of Vindonissa would total a minimum of 4,469 metric tons and a maximum of 6,300 metric tons of grain.

Providing such an amount of grain to Vindonissa would clearly have required large areas of land. At yields of between 650 kg per hectare and 865 kg per hectare, feeding the garrison alone would have called for a minimum of 2,735 hectares (to feed 5,760 men at yields of 865 kg per hectare) and a maximum of 4,547 hectares (to feed 7,200 men at yields of 650 kg per hectare) of arable land. The legion's cavalry horses would have required an additional 409 to 544 hectares, assuming that the feed grain grown for the horses yielded at the same rate as the wheat grown for the men. The pack animals would consume the produce of a further 1,433 to 1,907 hectares. Feeding the civilians would have required a minimum of 2,023 hectares and a maximum of 2,692 hectares in addition to the soldiers' needs. The total amount of land, therefore, needed to feed the population of Vindonissa would have been a minimum of 6,600 hectares and a maximum of 14,833 hectares. Once loss rates and reservations of seed grain are taken into consideration, the total minimum rises to 8,971 hectares and the maximum to 21,118 hectares. If the

⁵⁷ See Sommer (1984), 33

territorium at Vindonissa was similar in area to other theorized legionary *territoria*, the roughly 450 square kilometers it covered would encompass 45,000 hectares of land, more than enough to furnish the necessary area.

The distribution of this land around the fort is almost impossible to determine, though the civilian colony of Augusta Raurica, some 20 km west of Vindonissa may serve as one terminus of the legion-controlled land, if the situation at Vindonissa is similar to the situations at Carnuntum and Aquincum.⁵⁸ Vindonissa's theoretical *territorium* would also encompass land in the alluvial valleys of the Aare and Reuss rivers, which was of prime agricultural importance to the cultivation of cereals. Even if the primary purpose of the legionary *territorium* was to provide pasture and grazing for the legion's pack animals and cavalry horses, Vindonissa demonstrates that the entirety of the annual grain requirements for both the legions and the civilian residents could be obtained from a little over a fourth of the land theoretically controlled by the legion.

External Sources of Food

Vindonissa's prime position on the confluence of two rivers, as well as its proximity to two major roads, would have facilitated the importation of grain by several avenues, and it seems that the garrison here would have been able to rely on regular shipments from elsewhere more frequently. Importing grain may have been logistically easier for Vindonissa, but it still would have incurred transportation costs. Although Vindonissa also commanded the junction of two major roads, river transport would nevertheless be less expensive, and the orientation of the excavated granary at Vindonissa, near the north gate which opens onto the Aare river, shows that this mode of transport was probably the

⁵⁸ See Mason (1988), 168

most-commonly used. A first-century-A.D. papyrus from Egypt mentions the cost of river transport over roughly 19.5 km: a shipment of 267,897 *artabs* (roughly 10,447 metric tons) of wheat is tarified at 2,330 *artabs* (roughly 90 metric tons).⁵⁹ This would equate to a cost of roughly 0.08 percent of the cargo for the 19.5 km trip, or roughly 0.004 percent per kilometer, significantly cheaper than overland transportation by road. For a river boat of the typical size used to ferry grain along the Tiber from Ostia to Rome, with a capacity of roughly 54 to 63 metric tons (6,000 to 7,000 *modii*),⁶⁰ this charge would be roughly 216 kg to 252 kg (24 to 28 *modii*) per barge per kilometer. Equating this figure to the price of a *modius* of grain, perhaps two *denarii* per *modius* in the first century A.D.,⁶¹ gives a transport cost of roughly 48 to 56 *denarii* per barge per kilometer. Importing the entirety of the necessary grain supplies for Vindonissa would have demanded a minimum of 65 barges and a maximum of 87 barges of the same size as those used on the Tiber, resulting in total transport charges of a minimum 3,120 *denarii* and a maximum 4,872 *denarii* per kilometer. These barges could have originated at any one of the numerous Roman settlements along the Rhine valley, but if the majority of the imports were of bread wheat (*triticum aestivum*), the better-quality grain for bread-making, the archaeobotanical evidence would suggest that this type of wheat was grown predominantly in the Upper and Lower Rhine valleys, between Basel (Basilia) and Mainz (Mongontiacum); and between Neuss (Novaesium) and Nijmegen (Noviomagus), respectively.⁶² Basel would obviously represent the shortest trip, at roughly 30 km from Vindonissa, and Nijmegen the longest, at roughly 655 km. The minimum cost for river

⁵⁹ *BGU* 3.802

⁶⁰ Rickman (1980b), 267

⁶¹ Duncan-Jones (1974), 146

⁶² Rösch et al. (1992), 206

transport to Vindonissa, therefore, would have been 93,600 denarii (at 3,120 *denarii* per kilometer for the 30 kilometers to Basel), and the maximum cost would have been 3,191,160 *denarii* (at 4,872 *denarii* per kilometer for the 655 kilometers to Nijmegen). Clearly a wide range of transport costs were possible depending on exactly where the barges originated along the river, but even the minimum journey of 30 km would add a considerable surcharge to the cost of the grain itself versus local production in the legion's *territorium*.⁶³

The soldiers at Vindonissa also ate both local livestock and wild game. The bones of cattle, sheep and goats, and pigs have been found in the fort, as have eggshells and the bones of deer and boar.⁶⁴ Both fish bones and fish hooks have been found on the site, indicating that the soldiers took advantage of the nearby rivers as a source of food, though they also imported fish as well.⁶⁵ Plant evidence suggests that the legionaries also had access to a wide variety of fruit, both domestic products, such as apples and grapes, and imported varieties like figs and dates.⁶⁶ In addition to the beans and lentils which were probably part of their rations, the soldiers at Vindonissa also ate peas and carrots, perhaps provided to them by civilian traders.⁶⁷ The legionaries certainly imported foods, namely oysters from the Atlantic.⁶⁸ A collection of amphora labels found at Vindonissa also attest to the importation of vintage wine from Sicily and southern Italy, pickled olives, honey, *muria*, and beans.⁶⁹ The military garrison and the civilian settlement of

⁶³ These figures may of course be a steep overestimate of transport charges, as the cited tariff rate represents a maximum charge. It does, however, represent a useful benchmark for estimating costs in the absence of other figures related to river transport.

⁶⁴ Davies (1989), 192. Wild game appears to have been eaten less regularly than at other sites in Europe.

⁶⁵ Davies (1989), 194

⁶⁶ Jacomet et al. (2002), 88

⁶⁷ *CIL* 13.5221, mentioning the “vendors of salted vegetables”.

⁶⁸ Davies (1989), 193

⁶⁹ Davies (1989), 197

Vindonissa no doubt represented two important markets for both domestically-produced and imported foodstuffs, and the soldiers themselves clearly had access to a wide variety of foods.

The demand for supplies that the garrison of Vindonissa placed on its surrounding area were obviously much larger than the demands of the smaller garrisons of auxiliary forts. It seems, however, that Vindonissa, in the manner of many legionary fortresses, had at its disposal a *territorium* that encompassed an area of land large enough to produce not only the necessary supplies for the garrison, but also for the population of the civilian settlement. Transport of supplies by river was possible here as it was to the majority of the frontier forts on the Rhine, and the soldiers could and often did import food, but it seems that these imports were luxuries, such as vintage Italian wine and honey, rather than staples such as grain. Vindonissa's important tactical position as one of the three legionary bases in Upper Germany would have required a stable and consistent food supply, which could be more easily obtained from agriculture in the surrounding area than from long-distance transport.

Conclusion

Nullum ab Agricola positum castellum aut vi hostium expugnatum aut pactione ac fuga desertum, nam adversus moras obsidionis annuis copiis firmabantur... et sibi quisque praesidio...

“Not one fort established by Agricola was abandoned either on account of enemy action or treaty or surrender, for they were fortified against long sieges with a year’s supplies...and each garrison was supported by its own resources...”
Tac. Agr. 22.2-3

The above quote from Tacitus regarding “a year’s supplies” has been an important piece of evidence for studies of Roman military granary capacity, starting, for instance, with Collingwood and Haverfield’s 1918 study of British granaries.¹ It is the last part of the statement, “each garrison was supported by its own resources”, that is perhaps more intriguing in the context of this paper. These resources certainly existed, or else the garrisons would not have been able to remain viable on the remote margins of the Roman Empire. This paper has endeavored to explore the extent of these resources from the perspective of supplying the soldiers with grain, which was the most basic and most essential item of their daily diet. From the three case studies undertaken, representing the Near Eastern, British and German frontiers of the empire, it is evident that these garrisons in particular could be well-supplied with grain from the areas of arable land surrounding the fort. Doing so would also reduce both the costs of importation and the danger of supply line breakdown that would impact a frontier garrison’s viability.

The fort at Haurra would seem to be the fort most difficult to supply locally, given the limitations of cereal agriculture in a desert environment. Thin, sandy soil and low levels of rainfall would complicate any type of large-scale agriculture, especially the mass production of a bulk food product like grain. The establishment of a successful civilian

¹ Bulmer (1969), 7, referencing Collingwood, R.G, and F.H Haverfield. (1920). “The Provisioning of Roman Forts”. *Cumberland and Westmorland Antiquarian and Archaeological Society* 20. Pp. 127-42

settlement in the area, however, and the subsequent installation of a military garrison no doubt motivated by the same natural resources and access to water, as well as the cultivation of grain at the site in antiquity, contradicts this notion. It would seem that the careful water management system of the Nabataean settlement, continued in use through to the Roman period, would have amplified the suitability of the area for farming.

Hauarra clearly commanded sufficient resources to sustain a population of roughly 500 people, and the introduction of a Roman garrison of the same size does not seem to have adversely affected the civilian population in any measurable way. The granary in the fort could have held a year's supply of grain for a garrison of roughly 450 soldiers, and the likelihood that any cavalry troopers attached to the unit would be mounted on camels rather than on horses simplifies the amount of grain supplies required. Plant evidence from Hauarra shows that both drought-tolerant barley and more climatically sensitive wheat were being cultivated and processed on the site in the Roman period, and cereal farming continues in the area today in a manner relatively unchanged from what must have been practiced there in antiquity. According to consumption rates for soldiers and civilians, sowing rates for desert cereal cultivation, and potential yields in the type of runoff farming practiced at Hauarra in antiquity, the necessary annual grain crops to sustain both the military and civilian population of Hauarra could be derived from roughly 6.3 square kilometers of land. The best arable land in the vicinity of Hauarra covers roughly 40 square kilometers, so there was clearly a large surplus of land which would help to counteract the agricultural variability of the area. Hauarra's position on the Eastern desert frontier of the Roman Empire would have complicated external imports to the site. Though fish and shellfish were imported to the site from Aila on the Red Sea,

some 80 km away, the main route that grain imports would have had to take would have been overland from Palestine or Judaea, a much longer journey of roughly 190 km. According to the transport rates quoted in the *Edict on Maximum Prices*, overland transport of the entirety of the garrison's grain requirements would be very costly, and given the clearly available resources of land and water that the settlement at Haurra commanded, encouraging as much local production of grain as could be sustained would have been a prudent fiscal measure.

The fort at Vindolanda, and indeed, all the forts in the heavily-militarized zone of Hadrian's Wall, though established in what is considered an agriculturally marginal region for cereal cultivation, nevertheless had nearby sources of supply. The Tyne Gap and the other river valleys through the Pennines presented arguably the best agricultural land in the vicinity of the Wall forts, and the final line of the Wall along these river valleys cannot have been an accident. Pollen evidence from both Roman and native British sites along Hadrian's Wall shows that the systematic large-scale clearance of the regional forests was already underway before the Roman arrived, and so the land would have been free for cultivation when the garrisons were installed. Adaptations to farming systems in the central Pennines show that the Romans may have been actively encouraging agricultural expansion in this area in order to ensure stable production of food for the local garrisons.² The predominant cereals at Vindolanda appear to be barley and spelt, both of which were staple crops in Iron Age Britain before the arrival of the Romans. The garrison at Vindolanda appears to have fluctuated in size more often than the garrisons at Haurra and Vindonissa, as seen in the renovations of the early timber phases of the fort to increase and decrease the internal area, and similar modifications

² Stallibrass & Thomas (2008), 10

must have been made to the timber granaries of this phase as well, though remains of these timber buildings have not been found. The final report on the stone granary at Vindolanda has yet to be published, but it can be expected that it would have been large enough to hold the necessary supplies for the garrison of roughly 500 soldiers. The same climatic amelioration which made the Jordanian desert more agriculturally viable may also have affected cereal farming near Vindolanda; the climate of northern Britain may have been warmer and less wild during this period, allowing cereal farming in parts of northern Britain that were previously considered too marginal to sustain large-scale agriculture. The most optimistic yield ratios would require an area of roughly 7.4 square kilometers to sustain the garrison, while the lowest theorized yields would demand an area of roughly 36 square kilometers. It is not unreasonable to assume that the necessary area of land would be closer to the former figure than the latter: it is hard to accept that the river valleys around Hadrian's Wall, where cereal farming was already taking place prior to the Roman occupation, would be so marginal as to produce yields of only a little over 1.5-to-one (0.35 metric tons per hectare when the sowing rate is 216 kg per hectare), when runoff farming in low-quality soil in the Jordanian desert, as demonstrated by Haurra, might produce yields of four-to-one.

The legionary fort at Vindonissa represents perhaps the most large-scale system of local supply covered by this paper. The garrison of this site was by far the largest of the three forts studied; a full legion and perhaps some auxiliary units, rather than only a cohort or two as at Haurra and Vindolanda. Despite the larger garrison size, only one granary building has been found at Vindonissa, one that is only large enough to hold an annual supply for perhaps a cohort and a half, hardly the capacity one would expect from

a granary in such an established and important legionary base. Evidence from other legionary forts suggests that Vindonissa has several granaries that are yet to be excavated, and if the fort was to be sufficiently well-stocked with appropriate amounts of provisions, this must be the case. Calculations show that the annual amounts of grain necessary to feed both the legionary garrison at Vindolanda and the civilian population of the sizeable settlement which existed around the fort could be obtained from roughly 211 square kilometers of farmland. This area of land would be well within the theoretical size of the *territorium* which has been proposed for legionary fortresses.

How, then, do the conclusions of these case studies inform the question of whether a Roman garrison could rely on local supply for the majority of its yearly requirements of grain? It is clear that each garrison faced similar yield ratios of grain; between three and four times the sown seed, the ratio that Erdkamp assigns to the most marginal grain-producing areas of Europe in the Roman period, which would encompass the Roman frontier zones.³ It is also clear that such yields could sustain the needs of the garrison and the civilians from the arable land in the immediate area. Whittaker suggests that the frontiers of the Roman Empire were established where they were because the areas which became the frontier zones were the furthest afield that Roman garrisons would still be sustainable.⁴ The Antonine Wall, for instance, was abandoned only fifteen years after it was established because the local agricultural economy was unable to support the army garrisons to such an extent as the economy in the areas around Hadrian's Wall. The main factor of this sustainability must have been the food supply, and the supply of bulk food products like grain surely played the largest role. The ever-important factors of the time

³ (2005), 39

⁴ (1994), 86-87

and money involved in supplying these remote zones must have been important considerations when the garrison was installed. This paper has shown that it was both possible and financially expedient, not to mention tactically advisable, for the forts of the Roman frontier to command sufficient areas of land and sufficient areas of agricultural productivity to supply themselves with a year's worth of their most basic necessary foodstuff: grain.

Bibliography

- Adams, C.E.P.
 1999 "Supplying the Roman Army: Bureaucracy in Roman Egypt." Pp. 119-26 in A. Goldsworthy and I. Haynes, eds. *The Roman Army as a Community*. Journal of Roman Archaeology Supplement 34. Ann Arbor: Cushing-Malloy.
- Anderson, J.D.
 1992 *Roman Military Supply in North-East England: An Analysis of and an Alternative to the Piercebridge Formula*. Oxford: British Archaeological Reports.
- Baatz, D.
 2000 "Vegetius's Legion and the Archaeological Facts." Pp. 149-58 in R.J. Brewer, ed. *Roman Fortresses and their Legions*. London: Society of Antiquaries.
- Bakels, C. & S. Jacomet
 2003 "Access to Luxury Foods in Central Europe During the Roman Period: The Archaeobotanical Evidence." *World Archaeology* 34. Pp. 542-57
- Bidwell, P.T.
 1985 *The Roman Fort of Vindolanda at Chesterholm, Northumberland*. London: Historic Buildings and Monuments Commission
- Birley, R.
 1977 *Vindolanda: A Roman Frontier Post on Hadrian's Wall*. London: Thames and Hudson
- 1994 *Vindolanda Research Reports, New Series, Volume I: The Early Wooden Forts: The Excavations of 1973-76 and 1985-89, with some additional details from the excavations of 1991-93*. Vindolanda Trust: Bardon Mill.
- Birley, A.R.
 1997 "Supplying the Batavians at Vindolanda." Pp. 273-80 in W. Groenman-van Waateringe et al., eds. *Roman Frontier Studies: 1995 Proceedings of the XVth International Congress of Roman Frontier Studies*.
- Bishop, M.C.
 1999 "Praesidium: Social, Military and Logistical Aspects of the Roman Army's Provincial Distribution During the Early Principate." Pp. 111-18 in A. Goldsworthy and I. Haynes, eds. *The Roman Army as a Community*. Journal of Roman Archaeology Supplement 34. Ann Arbor: Cushing-Malloy.

- Bowman, A.K. & J.D. Thomas
1991 "A Military Strength Report from Vindolanda." *Journal of Roman Studies* 81: 62-73
- 1994 *The Vindolanda Writing Tablets: Tabulae Vindolandenses II*. London: British Museum
- Breeze, D. J.
1993 "Demand and Supply on the Northern Frontier." Pp. 526-52 in D.J. Breeze and B. Dobson, eds. *Roman Officers and Frontiers*. Stuttgart: Franz Steiner
- Bruins, H.J.
1986 *Desert Environment and Agriculture in the Central Negev and Kadesh Barnea During Historical Times*. Nijerk, Netherlands: MIDBAR Foundation.
- Bulmer, W.
1969 "The Provisioning of Roman Forts." *Archaeologia Aeliana* 4.47: 7-13
- Cappers, R.T.J.
2006 *Roman Foodprints at Berenike: Archaeobotanical Evidence of Subsistence and Trade in the Eastern Desert of Egypt*. Los Angeles: Cotsen Institute of Archaeology at UCLA
- Casson, L.
1980 "The Role of the State in Rome's Grain Trade." *Memoirs of the American Academy in Rome* 36. Pp. 21-33
- Cherry, D
2007 "The Frontier Zones." Pp. 720-40 in W. Scheidel, I. Morris, & R. Saller, eds. *The Cambridge Economic History of the Greco-Roman World*. Cambridge: Cambridge University Press
- Coello, T.
1996 *Unit Sizes in the Late Roman Army*. Oxford: British Archaeological Reports International Series.
- Davies, J.L.
2009 "Size Matters: Campaign Forts in Britain." Pp. 43-54 in W.S. Hanson, ed. *The Army and Frontiers of Rome*. *Journal of Roman Archaeology Supplement* 74 Dexter, MI: Thomson-Shore.
- Davies, R.
1971 "The Roman Military Diet." *Britannia* 2: 122-42.

- 1989 *Service in the Roman Army*. Edinburgh: Edinburgh University Press
- Dixon, K., & P. Southern.
1992 *The Roman Cavalry From the First to the Third Century AD*. London.
 Batsford
- Duncan-Jones, R.
1974 *Economy of the Roman Empire: Quantitative Studies*. Cambridge:
 Cambridge University Press.
- Eadie, J.W., & J.P. Oleson
1986 “The Water-Supply Systems of Nabataean and Roman Humayma.”
 Bulletin of the American Schools of Oriental Research 262: 49-76
- Elton, H.
1996 *Frontiers of the Roman Empire*. Indianapolis: Indiana University Press
- Erdkamp, P.
2002 “The Corn Supply of the Roman Armies During the Principate.” Pp. 47-69
 in P. Erdkamp, ed. *The Roman Army and the Economy*. Amsterdam: J.C.
 Gieben.
- 2005 *The Grain Market in the Roman Empire: A Social, Political, and
 Economic Study*. Cambridge: Cambridge University Press
- Finnegan, M.
In Preparation “Analysis of Faunal Remains Recovered from Humayma, Jordan.”
 Ch. 10B in J.P. Oleson, ed. *Humayma Excavation Project Vol. 2*.
 Pp. 11-25
- Forbes, H.A. & L. Foxhall.
1982 “Sitometreia: The Role of Grain as a Staple Food in Classical Antiquity.”
 Chiron 12: 41-90.
- Garnsey, P.
1988 *Famine and Food Supply in the Graeco-Roman World: Responses to Risk
 and Crisis*. Worcester: Billing & Sons
- Gauthier-Pilters, H. & A.I. Dagg
1981 *The Camel: Its Evolution, Ecology, Behavior, and Relationship to Man*.
 Chicago: University of Chicago Press
- Gent, H., and P. Dark
2001 “Pests and Diseases of Prehistoric Crops: A Yield ‘Honeymoon’ for Early
 Grain Crops in Europe?” *Oxford Journal of Archaeology*, 20. Pp. 59-78

- Gentry, A.
1976 *Roman Military Stone-Built Granaries in Britain*. Oxford: British Archaeological Reports.
- Gichon, M.
2000 "The Siege of Masada." Pp. 541-56 in Y. Le Bohec, ed. *Les Legions de Rome sous le Haute-Empire*. Lyon.
- Goodchild, H.
2007 *Modeling Roman Agricultural Production in the Middle Tiber Valley, central Italy*. Birmingham: University of Birmingham School of Historical Studies
- Groenman-van Waateringe, W.
1997 "Classical Authors and the Diet of Roman Soldiers: True or False?" Pp. 261-65 in W. Groenman-van Waateringe, B.L. van Beek, W.J.H. Willems & S.L. Wynia, eds. *Roman Frontier Studies 1995: Proceedings of the XVIth International Congress of Roman Frontier Studies*
- Henry, D.O.
1987 "Topographic Influences on Epipaleolithic Land-use Patterns in Southern Jordan." Pp. 21-27 in A. Hadidi, ed. *Studies in the History and Archaeology of Jordan III*. London. Routledge
- Holder, P.A.
1980 *Studies in the Auxilia of the Roman Army from Augustus to Trajan*. Oxford: British Archaeological Reports International Series 70.
- Hyland, A.
1990 *Equus: The Horse in the Roman World*. London: Batsford
- Jacomet, S., D. Kučan, A. Ritter, G. Suter, and A. Hagendorn
2002 "Punica Granatum L. (Pomegranates) from Early Roman Contexts in Vindonissa (Switzerland)." *Vegetation History and Archaeobotany* 11. Pp. 79-92
- Jobling, W.J.
1984 "The Fifth Season of the 'Aqaba-Ma'an Survey, 1984." *Annual of the Department of Antiquities of Jordan*, 28: 191-202
- Johnson, A.
1983 *Roman Forts of the First and Second Centuries AD in Britain and the German Provinces*. London: A & C Black
- Jones, A.H.M

- 1964 *The Later Roman Empire, 284-602: A Social, Economic, and Administrative Survey*. Oxford: Blackwell
- Jones, M.
1991 "Food Production and Consumption: Plants." Pp. 21-8 in R.F.J. Jones, ed. *Britain in the Roman Period: Recent Trends*. Sheffield: J.R. Collis
- Jones, M.E.
1996 *The End of Roman Britain*. Ithaca: Cornell University Press
- Laur-Belart, R.
1935 *Vindonissa: Lager und Vicus*. Berlin: Deutsches Archäologisches Institut
- Lepper, F. & S. Frere
1988 *Trajan's Column: A New Edition of the Cichorius Plates*. Stroud: Sutton
- Manning, A., R. Birley, and R. Tipping
1997 "Roman Impact on the Environment at Hadrian's Wall: Precisely Dated Pollen Analysis from Vindolanda, Northern England." *The Holocene* 7.2, 175-86
- Manning, W.H.
1975a "Roman Military Timber Granaries in Britain." *Saalburg Jahrbuch* 32. Pp. 105-29
- 1975b "Economic Influences on Land Use in the Military Areas of the Highland Zone During the Roman Period." Pp. 112-16 in J.G. Evans et al., eds. *The Effect of Man on the Landscape: The Highland Zone*. London: CBA Research Report No. 11
- MacDonald, B.
2001 "Relation Between Paleoclimate and the Settlement Patterns of Southern Jordan during the Nabataean, Roman, and Byzantine Periods." Pp. 373-78 in *Studies in the History and Archaeology of Jordan VII*. Amman: Department of Antiquities.
- Mason, D.J.P
1987 "Chester: The Canabae Legionis." *Britannia* 18. Pp. 143-68
- 1988 "Prata Legionis in Britain." *Britannia* 19. Pp. 163-89
- Monfort, C.C.
2002 "The Roman Military Supply During the Principate: Transportation and Staples." Pp. 70-89 in P. Erdkamp, ed. *The Roman Army and the Economy*. Amsterdam: J.C. Geiben.

- Oleson, J.P.
 1997 "Landscape and Cityscape in the Hisma: The Resources of Ancient Al-Humayma." Pp. 175-88 in *Studies in the History and Archaeology of Jordan VI*. London: Routledge.
- 2007 "Trajan's Engineers and the Roman Fort at Al-Humayma (Ancient Hawara, Jordan)." Pp. 535-48 in *Studies in the History and Archaeology of Jordan X*. London: Routledge
- 2010 *Humayma Excavation Project I: Resources, History and the Water Supply System*. Boston: American Schools of Oriental Research.
- Oleson, J.P., G.S. Barker, E. De Bruijn, R.M. Foote, J. Logan, M.B. Reeves, and A.N. Sherwood.
 2003 *Preliminary Report of Al-Humayma Excavation Project, 2000, 2002*. Amman: Department of Antiquities of Jordan
- Oleson, J.P., M.B. Reeves, G.S. Baker, E. de Bruijn, Y. Gerber, M. Nikolic, and A.N. Sherwood.
 2008 *Preliminary Report on Excavations at Al-Humayma, Ancient Hawara, 2004 and 2005*. Amman: Department of Antiquities of Jordan
- Parker, S.T.
 2000 "Legionary Fortresses in the East." Pp. 121-38 in R.J. Brewer, ed. *Roman Fortresses and their Legions*. London: Society of Antiquaries
- 2006 *The Roman Frontier in Central Jordan: Final Report on the Limes Arabicus Project, 1980-1989*. Washington: Dumbarton Oaks
- Pearce, J.
 2002 "Food as Substance and Symbol in the Roman Army: A Case Study from Vindolanda." Pp. 931-44 in P. Freeman et al., eds. *Limes XVIII: Proceedings of the XVIIIth International Congress of Roman Frontier Studies*
- Raepsaet, G.
 2008 "Land Transport: Riding, Harnesses, and Vehicles." Pp. 581-605 in J.P. Oleson, ed. *The Oxford Handbook of Engineering and Technology in the Classical World* New York: Oxford University Press.
- Rathbone, D. W.
 2007 "Roman Egypt." Pp. 698-719 in W. Scheidel, I. Morris, & R. Saller, eds. *The Cambridge Economic History of the Greco-Roman World*. Cambridge: Cambridge University Press
- Ramsay, J.

- In Preparation “Plant Remains.” Ch. 10.D in J.P. Oleson, ed. *Humayma Excavation Project Vol. 2*. Pp. 39-48
- Richardson, A.
 2004 “Granaries and Garrisons in Roman Forts.” *Oxford Journal of Archaeology* 23.4: 429-42.
- Rickman, G.
 1971 *Roman Granaries and Store Buildings*. London: Cambridge University Press
- 1980a *The Corn Supply of Ancient Rome*. Oxford: Clarendon Press
- 1980b “The Grain Trade Under the Roman Empire.” *Memoirs of the American Academy in Rome* 36: 261-75.
- Roth, J.P.
 1994 “The Size and Organization of the Roman Imperial Legion.” *Historia: Zeitschrift für Alte Geschichte* 43 (3). Pp. 346-62
- 1999 *The Logistics of the Roman Army at War (264 B.C.-A.D. 235)*. Leiden: Brill
- 2002 “The Army and the Economy in Judaea and Palestine.” Pp. 375-97 in P. Erdkamp, ed. *The Roman Army and the Economy*. Amsterdam: J.C. Gieben.
- Rösch, M., S. Jacomet, and S. Karg
 1992 “The History of Cereals in the Region of the Former Duchy of Swabia (*Herzogtum Schwaben*) from the Roman Period to the Post-Medieval Period: Results of Archaeobotanical Research.” *Vegetation History and Archaeobotany*, 1. Pp. 193-231
- Sallares, R.
 1991 *The Ecology of the Ancient Greek World*. Ithaca: Cornell University Press
- Schönberger, H.
 1969 “The Roman Frontier in Germany: An Archaeological Survey.” *The Journal of Roman Studies*, 59. Pp. 144-97
- Shehadeh, N.
 1985 “The Climate of Jordan in the Past and Present.” Pp. 25-37 in A. Hadidi, ed. *Studies in the History and Archaeology of Jordan II*. London: Routledge.
- Shirley, E.

- 2001 *Building a Roman Legionary Fortress*. Stroud: Tempus
- Sommer, C.S.
1984 *The Military Vici in Roman Britain: Aspects of Their Origins, Their Location and Layout, Administration, Function, and End*. Oxford: British Archaeological Reports
- Spurr, M.S.
1986 *Arable Cultivation in Roman Italy, c. 200 B.C.-c. A.D. 100*. London: Journal of Roman Studies Monographs 3.
- Stallibrass, S. & R. Thomas.
2008 *Feeding the Roman Army: The Archaeology of Production and Supply in NW Europe*. Oxford: Oxbow
- Sykes, E.C.
1933 "The Agricultural Geography of Northumberland." *Geography*, 18 (4). Pp. 269-82
- Van der Veen, M., & S. Hamilton-Dyer
1998 "A Life of Luxury in the Desert? The Food and Fodder Supply to Mons Claudianus." *Journal of Roman Archaeology* 11. Pp. 101-116
- Van-Driel Murray, C., J.P. Wild, M. Seaward, and J. Hillam
1993 *Vindolanda Research Reports, New Series, Volume 3: Preliminary Reports on the Leather, Textiles, Environmental Evidence and Dendrochronology*. London: Bardon Mill.
- Vindolanda Charitable Trust
2008 *Excavation News 2008*.
www.vindolanda.com/LiteratureRetrieve.aspx?ID=41542.
Accessed 3/27/2012
- Walker, R.
1974 "Roman Cavalry Rations: A Calculation of the Daily Ration of Barley Issued to the Troop Horse." *Veterinary History* VE.4, 16-19.
- White, K.D.
1970 *Roman Farming*. London: Thames and Hudson.
- Whittaker, C.R.
1994 *Frontiers of the Roman Empire: A Social and Economic Study*. Baltimore: Johns Hopkins University Press

- 2002 “Supplying the Roman Army: Evidence from Vindolanda.” Pp. 204-34 in P. Erdkamp, ed. *The Roman Army and the Economy*. Amsterdam: J.C. Gieben.

Appendix A: Total Annual Requirements of Grain for Haurra, Vindolanda, and Vindonissa

I have included the following appendices in order to provide a synoptic view of the data presented in Chapters Three, Four, and Five.

Appendix A summarizes the annual demand of grain in metric tons of the three sites covered in this paper.

Table 6: Annual Requirements of Grain for Haurra (Metric Tons)

	<i>Soldiers</i>	<i>Animals</i>	<i>Civilians</i>
<i>Minimum Requirements</i>	162	0	131
<i>Maximum Requirements</i>	162	116	131

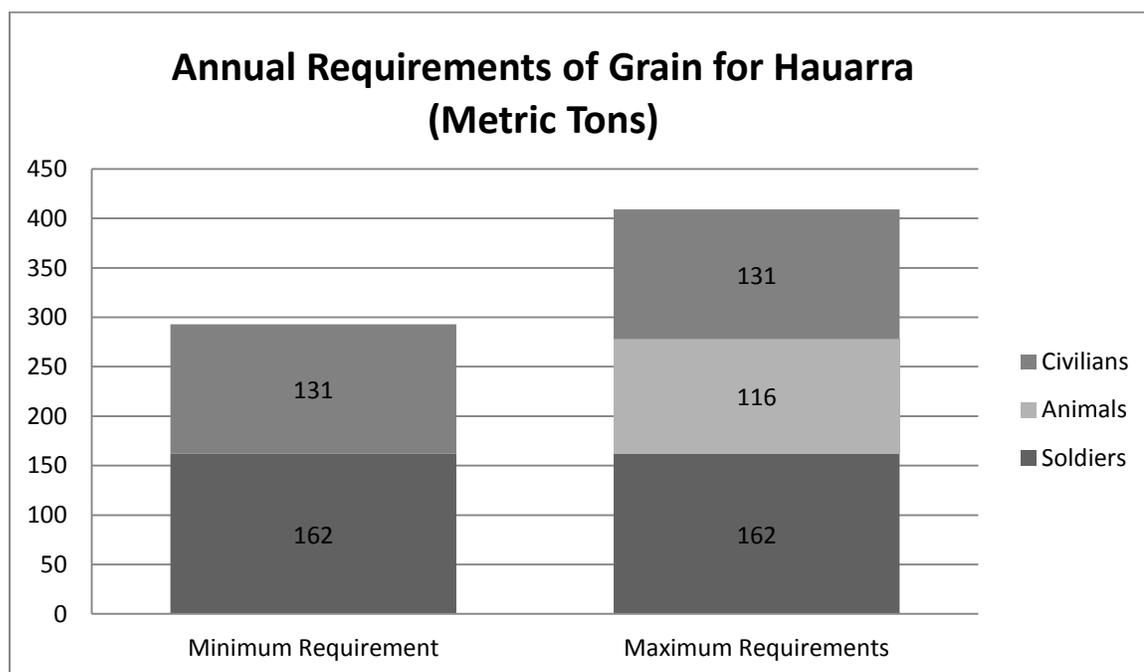


Table 7: Annual Grain Requirements for Vindolanda (Metric Tons)

	<i>Soldiers</i>	<i>Animals</i>	<i>Civilians</i>
<i>Minimum Requirements</i>	197	142	146
<i>Maximum Requirements</i>	328	375	146

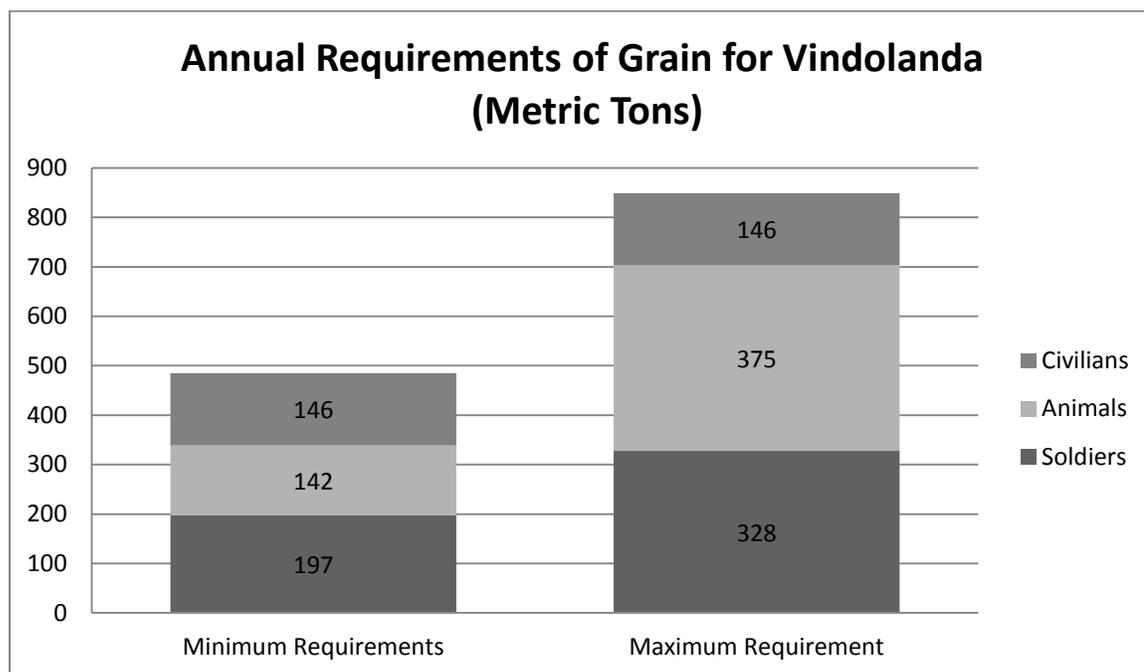
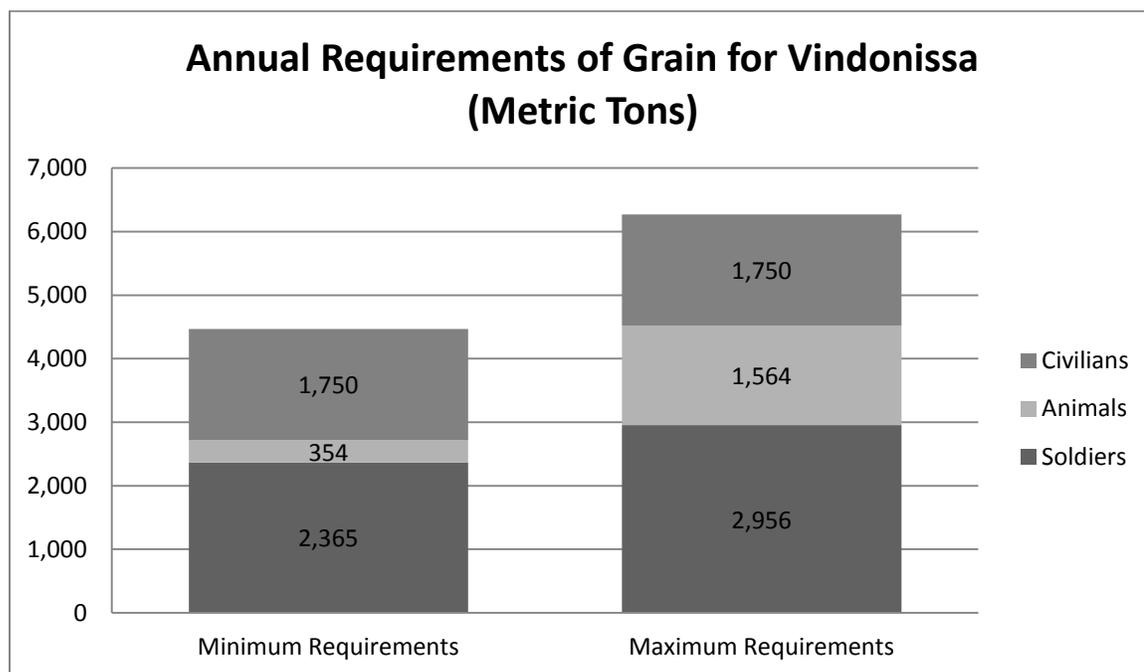


Table 8: Annual Requirements of Grain for Vindonissa (Metric Tons)

	<i>Soldiers</i>	<i>Animals</i>	<i>Civilians</i>
<i>Minimum Requirements</i>	2,365	354	1,750
<i>Maximum Requirements</i>	2,956	1,564	1,750



Appendix B: Transportation Costs to Haurra, Vindolanda, and Vindonissa

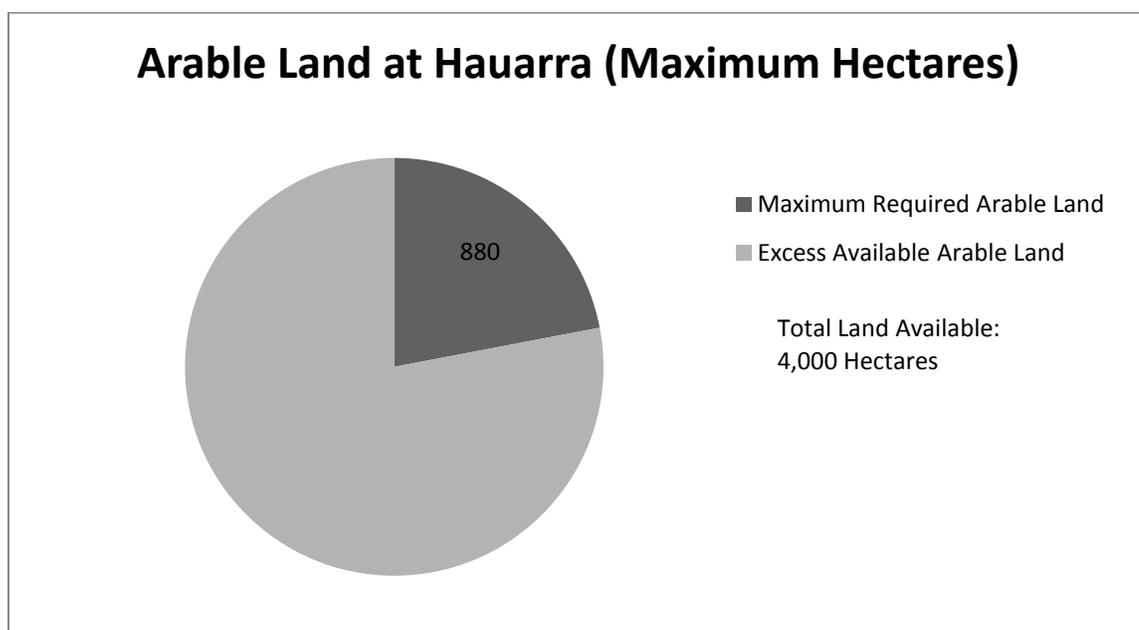
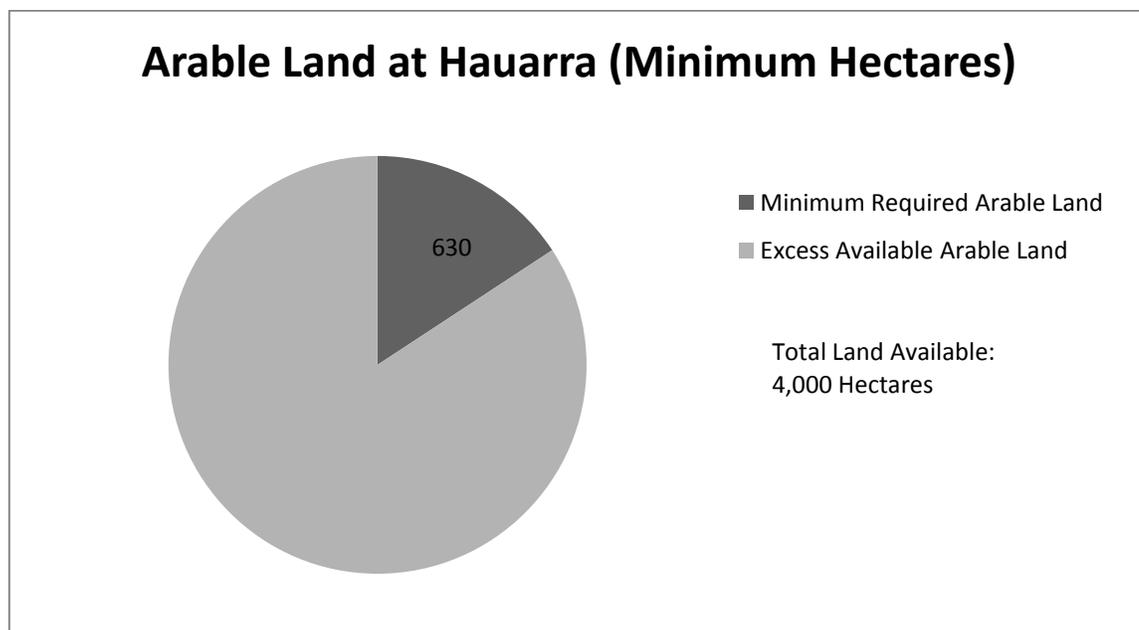
Appendix B summarizes the costs of external transportation to the three sites in question.

Table 9: Summary of Minimum and Maximum Transportation Costs

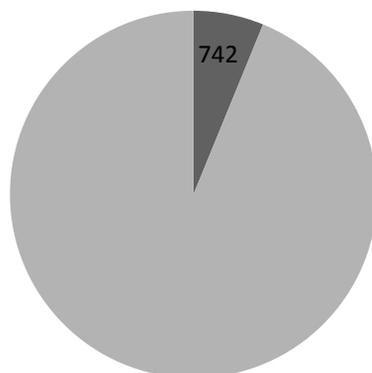
	<i>Kilograms of Grain per Unit of Transport</i>	<i>Number of Units of Transport Required (Min./Max.)</i>	<i>Kilometers Traveled (Min./Max.)</i>	<i>Transport Rate Per Kilometer (Min./Max.)</i>	<i>Total Transport Costs (Min./Max.)</i>
<i>Haurra</i>	270 kg per camel	600 camels	190 km	0.30 <i>denarii</i>	34,200 <i>denarii</i>
				13 <i>denarii</i>	1,500,000 <i>denarii</i>
<i>Vindolanda</i>	540 kg per wagon	287 wagons	55 km	12 <i>denarii</i>	189,000 <i>denarii</i>
		574 wagons	60 km		413,000 <i>denarii</i>
<i>Vindonissa</i>	Between 54 metric tons and 63 metric tons per barge	65 barges	30 km	48 <i>denarii</i>	93,600 <i>denarii</i>
		87 barges	655 km	54 <i>denarii</i>	3,100,000 <i>denarii</i>

Appendix C: Total Arable Land Requirements for Huarra, Vindolanda, and Vindonissa

Appendix C summarizes the areas of arable land needed to supply the annual grain requirements of the three sites in question.



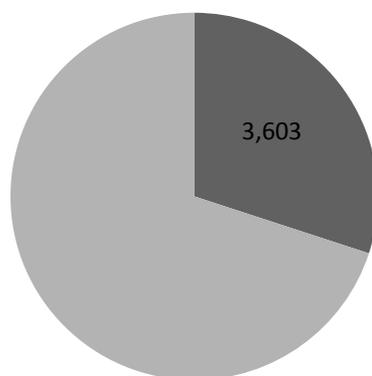
Arable Land at Vindolanda (Minimum Hectares)



- Minimum Required Arable Land
- Excess Available Arable Land

Total Land Available:
12,000 Hectares

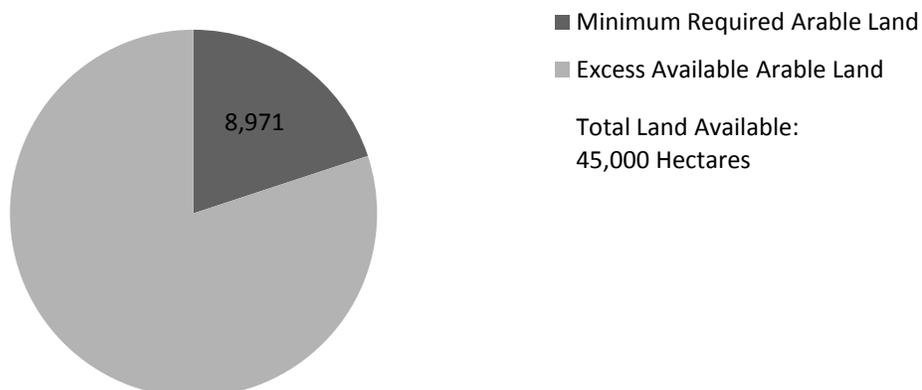
Arable Land at Vindolanda (Maximum Hectares)



- Maximum Required Arable Land
- Excess Available Arable Land

Total Land Available:
12,000 Hectares

Arable Land at Vindonissa (Minimum Hectares)



Arable Land at Vindonissa (Maximum Hectares)

