Ostali članci / Other topics:

USE AND MANAGEMENT OF NATURAL RESOURCES IN IRONMAKING IN THE SLOVENIAN TERRITORY BETWEEN THE 14TH AND 16TH CENTURIES

KORIŠTENJE I UPRAVLJANJE PRIRODNIM RESURSIMA U PROIZVODNJI ŽELJEZA NA SLOVENSKOM TERITORIJU IZMEĐU 14. I 16. STOLJEĆA

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Summary

The paper addresses the utilisation and management of natural resources, particularly forests, for ironmaking purposes in Slovenian lands. Until the 19th century, wood charcoal was the primary fuel used for iron extraction and processing. With the development of intensive ironmaking, charcoal consumption began to increase, but until the 16th century, it did not pose significant threats to the existence of forests. Proprietors of ironmaking plants had to obtain permission from seigniories to use forests, and in return, they paid dues that varied across different seigniories. From the late 15th century, disputes related to logging for charcoal production became more frequent, involving conflicts among ironworkers from different seigniories and between ironworkers and a seigniory. The latter resulted from enforcing the princely mining regalia and forest ownership in mining areas. The territorial prince reinforced this ownership through the issuance of mining regulations in 1517, 1553, and 1575, which also provided instructions for forest management. Each successive mining regulations contained more detailed provisions regarding deforestation, indicating a growing number of areas deforested for ironmaking purposes. The last part of the paper attempts to estimate the annual charcoal consumption and deforestation rate for ironmaking needs in Carniola and Gorizia, as well as the Jesenice ironmaking area, in the late 16th century. Due to the scarcity of preserved sources documenting charcoal consumption, and consequently the use of numerous more or less reliable variables in the calculation, the obtained results should be approached with a considerable degree of critical distance. Nevertheless, the estimates suggest that even during this period, relatively extensive forest areas had to be cleared for iron extraction and processing.

Keywords: Forest, water power, charcoal, ironmaking, Late Middle Ages, 16th century, Slovenia
Ključne riječi: šuma, vodena snaga, drveni ugljen, proizvodnja željeza, kasni srednji vijek, 16. stoljeće, Slovenija

INTRODUCTION[1]

Intensive ironmaking in the Slovenian territory[2] began around the mid-14th century. Between the 14th and 16th centuries, the main centres of iron production were in the north-western part of the present-day Republic of Slovenia (the Selca and Upper Sava Valleys, the settlements of Kropa and Kamna Gorica, and the Bohinj area), as well as in the neighbouring areas of Fusine in Valromana (Bela Peč/Weissenfels) and the Canal Valley (Val Canale/Kanalska dolina/Kanaltal). Throughout the pre-industrial period, waterpower and charcoal were the main natural resources used to extract and process iron. The introduction of waterpower to drive ironworks was a key factor in developing intensive ironmaking, as it allowed greater iron production in a single smelting process and the operation of larger trip hammers for processing iron into semi-finished products.[3] Charcoal was used as a fuel for smelting iron ore in smelting furnaces, heating iron and iron semi-finished products in hearths throughout the subsequent processing steps, and manufacturing final products. It was obtained by burning dry wood in charcoal piles, usually using wood from the vicinity of ironmaking plants, if available. The increased production of iron and iron products in the Late Middle Ages led to increased demand for charcoal.

USE AND MANAGEMENT OF NATURAL RESOURCES UNTIL THE LATE 15TH CENTURY

In the Late Middle Ages, feudal landlords, as owners of forest and water rights,[4] usually granted ironworks proprietors not only permission to work and exploit iron ore but also rights to use forests and, less frequently, water resources. In some cases, these rights were territorially limited. In return, proprietors had to pay dues to the seigniory, sometimes in the form of joint payments, while in certain cases, specific dues for the use of forests were set, known as "forest dues" (*waldzins*).

Ironmaking masters in the area of the present-day settlement of Železniki in the Selca Valley were granted the rights to use the forest soon after they started operating in the area. The landlord, Bishop Albert II of Freising, issued a charter in 1358,[5] demarcating the land near the ironmaking plants and allowing the felling of trees, the transport and storage of wood in the area and the use of existing roads (*waz sy in der selben eben holcz nider slahen vermugen sy daz selb furben vnd rawmen daz schullen sy nuczen vnd niezzen*). No specific charge for the use of forests is mentioned in the document.[6]

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1 This paper was prepared as part of Objects and Prestige: Taste, Status, and Power (Researches on the Material Culture in Slovenia) (P6-0282), a research programme co-funded by the Slovenian Research and Innovation Agency (ARIS). An abstract was presented at the 12th Conference of the European Society for Environmental History (ESEH) in Bern, Switzerland, in August 2023.

2 The term "Slovenian territory" or "Slovenian Lands" in this paper refers to the area of the present-day Republic of Slovenia and its immediate neighbourhood where the Slovenian minority is still present today. Historically, it refers to the areas of Carniola, and parts of County of Gorizia, Carinthia, Styria, and Hungary (the Prekmurje and Porabje regions).

3 OITZL, Gašper: Obuditev in razvoj metalurških dejavnosti. Metalurgija na Slovenskem v srednjem veku / Revival and Development of Metallurgical Activities. Metallurgy in Slovenian Territory in the Middle Ages. In: *Ko zapoje kovina. Tisočletja metalurgije na Slovenskem / The Song of Metal. Millennia of Metallurgy in Slovenia*, eds. Jernej Kotar, Tomaž Lazar, Peter Fajfar. Ljubljana: Narodni muzej Slovenije, 2019, pp. 74–81; OITZL, Gašper: The Transfer of Ironworking Technologies in Slovenian Territory between the 14th and 16th Centuries. In: *Secrets of Iron – from Raw Material to an Iron Object. Proceedings of the 7th International Conference of Mediaeval Archaeology of the Institute of Archaeology. Zagreb, 10th–11th September 2020*, eds. Tajana Sekelj Ivančan et al. Zagreb: Institute of Archaeology, 2022, pp. 209–211.

4 Uncultivated land, including water bodies and forests, and the right to use them, were not inherently the property of seigniories. Like the right to a high justice, the right-to-use belonged to territorial seigniories, from which territorial courts (Landgericht) evolved. VILFAN, Sergij: *Pravna zgodovina Slovencev: od naselitve do zloma stare Jugoslavije*. Ljubljana: Slovenska matica, 1961, pp. 82, 136, 211; ŠTIH, Peter: Mensch und Wald in den Ostalpen (bis zur großer Kolonisation). In: *Man, Nature and Environment between the Nordern Adriatic and the Eastern Alps in Premodern Times*, eds. Peter Štih, Žiga Zwitter. Ljubljana: Znanstvena založba Filozofske fakultete, 2014, pp. 42–48. The seigniories, in which extensive ironmaking activities took place between the 14th and 16th centuries and are the subject of this paper, had the jurisdiction of a territorial court, as well as the right to use the uncultivated world.

5 In the first charter granted in 1354, no specific rights with regard to forest use are mentioned. It is safe to assume, however, that they were included in the general work permit issued by Bishop Albert. DE-BayHStA, HL 4, Hochstift Freising, fasc. 135, 1379 4/29; ZIMK SAZU, CKSL, 1354 6/9.

6 DE-BayHStA, HL 4, Hochstift Freising, fasc. 135, 1379 4/29; ZIMK SAZU, CKSL, 1358 10/16. In the 14th and 15th centuries, the masters in Železniki received numerous new privileges which are not preserved. Globočnik speculates that some of these privileges, such as

Fig. 1. *Map showing the most important ironmaking centres in Slovenia between the 14th and 16th centuries (marked in light font).*

During approximately the same period, similar permissions were granted to proprietors of ironworks in Canal Valley, where iron-processing plants primarily worked with iron from Carinthia. Permissions were issued by the *vicedominus* (Vizedom) of the Bamberg Diocese in Carinthia, in agreement with other diocesan officials. Unlike proprietors in the Selca Valley, those in Canal Valley had to pay substantial one-off dues for permission to work there and use the forest. For instance, Franciscus, an ironmaking master who in 1354 received permission to set up a forge with two trip hammers near the settlement of Laglesie San Leopoldo (Lipalja vas/Leopoldskirchen), had to pay the diocese a one-off sum of 42 gold coins. This included permission to use the forest for charcoal production. The use of the forest was limited to the valley of the Fella River (Bela/Vellach) between the settlements of Laglesie San Leopoldo and Pontebba (Tablja/Pontafel).[7] Similarly, Rupel Leininger, a burgher of Villach, who received the right to set up a forge in Canal Valley a year later, had to pay a one-off dues of 30 gold coins in order to obtain the permission and use the diocesan forests. He also committed to using the wood solely for charcoal production and not to sell the charcoal to others.[8]

In the Late Middle Ages, the Diocese of Bamberg was the only landowner in the Slovenian territory to demand high additional dues for the construction of new ironmaking plants, also as compensation for the use of forests. In Fusine in Valromana, adjacent to Canal Valley and also the site of primarily iron-processing plants, ironmaking masters received feudal grants that stipulated only the payment of annual dues. These dues usually included a fee for forest use, commonly listed together with water as an accessory of the forge (*vnnd wald vnnd wasser, was er des bedarff zu seiner schmitten*).[9]

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those from 1388, 1416, 1423, 1430, 1454, and 1479, also pertained to forest use. His speculation is based on the content of a document from 1589, in which masters sought confirmation of earlier privileges, specifically those related to forest use. GLOBOČNIK, Anton: Geschichtlich-statistischer Ueberblick das Bergortes Eisnern. *Mittheilungen des historischen Vereines für das Herzogthum Krain* 22, 1867, p. 9.

7 WIESSNER, Hermann: *Monumenta historica ducatus Carinthiae: geschichtliche Denkmäler des Herzogtums Kärnten X*. Klagenfurt: Geschichtverein für Kärnten, 1968, no. 410.

8 WIESSNER, H., *Monumenta X*, no. 432.

9 SI-ARS, AS 1, box 117, Der von Weissenfels Freyhaiten, f. 46; AT-KLA, KLA 112, AHS, 2732, Urbar Weissenfels 1636, f. 414–418; ZIMK SAZU, CKSL, 1455 10/22; MLINAR, Janez: Das Eisenhüttenwesen und sein Einfluss auf Mensch und Natur in Spätmittelalter und Frühneuzeit. Beispiele aus dem westlichen Oberkrain. In: *Man, Nature and Environment between the Northern Adriatic and the Eastern Alps in Premodern Times*, eds. Peter Štih, Žiga Zwitter. Ljubljana: Znanstvena založba Filozofske fakultete, 2014, p. 188. Similar examples can also be found in Carinthia. For example, in the office of Prossing near Gmünd, in 1445, forest is mentioned as an accessory to the trip hammer (*mit allen wälden so zw dem selben hamer gehörent*). AT-HHStA, Salzburg, Erzstift, AUR, 1445 7/24.

From 1385, the area of Fusine in Valromana shared the landlord with another major ironmaking area in Carniola, namely the "mountains above Jesenice" (*Eysena*[e]*rtz Assnig in der Alben*).[10] In accordance with the mining regulations (Bergordnung) issued in 1381 by the landlord Frederick III of Ortenburg, proprietors of ironmaking plants in this area were obliged to pay forest dues (*walden zinss*) as part of the combined annual dues.[11] Given Frederick's active role in establishing the iron industry in the Radovljica seigniory,[12] it is not surprising that he did not want to impose high or additional dues on existing or potential future ironmaking masters and plant proprietors.

By issuing the mining regulations, Frederick sought to regulate the management of the forests around iron ore deposits. The use of natural resources in this area[13] was almost exclusively reserved for mining and ironmaking activities and was not restricted in any way. Control over felling and charcoal burning (*kolmachen*, *holzmachen*) fell under the jurisdiction of the mining magistrate (Bergrichter), elected annually from among ironmaking masters of the Jesenice ironmaking area. The masters had full forest use rights (*mit allen irn rechtn vnd nutzen der wald der artzpergs mit aller suchung vnd handlung die darzu gehörtt*), but further assarting was not allowed (*keiner rautter stifften noch setzen an das gepirg ob Asnigkh*). The pastures above Jesenice were also reserved exclusively for ironmaking masters for their own food supply. Any surplus hay could only be sold among masters.[14]

The two initially most common ways of supplying ironmaking plants with charcoal were the forest as an accessory to the plant and the right to use the forest typically located in the immediate vicinity of the plant. In addition to these, two other methods became more common over time. One was the granting of a specific area of forest, a so-called clearing or forest plot (*Schlag*), which could be located in a more remote area and be temporarily restricted, again in return for the payment of dues. An example survives from central Carinthia, where in 1429, Bishop Frederick III of Bamberg granted the blacksmiths of Feldkirchen permission to clear forest within the designated boundaries around Goggau, north of Feldkirchen, in return for an annual dues of 10 Viennese *schillings*.[15] The last method of supply, which also became more common over time, was to purchase charcoal from neighbouring farmers. An example of this is known from the Friesach area around 1500.[16]

Specific dues for the use of waterpower are more frequent in the sources from the mid-15th century onwards. Such dues were apparently already in force in Hüttenberg, the largest ironmaking centre in Carinthia, when in 1468, Archbishop Bernhard of Salzburg instructed both the captain and the *vicedominus* in Friesach to ensure that proprietors of ironmaking plants pay dues for the use of waterpower.[17] The Weissenfels seigniory's rent roll of 1498 states that proprietors must pay 12 Venetian *soldi* for each new waterwheel that uses waterpower to power an economically productive facility. Mills, stamping presses for grain threshing (*stampf*), and forges are specifically mentioned.[18] An example of the special treatment of economic establishments operating by a watercourse and utilising waterpower can be found in the late 15th-century rent roll of the *vicedominus* office in Carniola. One page from the rent roll lists

[10] MLINAR, Janez: Slepo črevo Kranjske. Prispevek h kolonizacijski zgodovini Zgornjesavske doline. *Zgodovinski časopis* 59, 2005, p. 336.

[11] LAČEN-BENEDIČIČ, Irena: *Ortenburški rudarski red*. Planina pod Golico: Krajevna skupnost, 2001, p. 14.

[12] Cf. MLINAR, Janez: Povednost srednjeveških urbarjev. Primer belopeškega urbarja iz leta 1498. In: *Urbarji na Slovenskem skozi stoletja*, eds. Lilijana Žnidaršič Golec, Matjaž Bizjak. Ljubljana: Arhiv Republike Slovenije, 2016, p. 51; OITZL, G., *Obuditev in razvoj*, pp. 66–71.

[13] The mining regulations designated the territorial area of the mining magistrate's jurisdiction and, consequently, the mining and ironmaking area as the area between the Karavanks to the north, the Sava River to the south, and the Jesenica and Ukova Streams to the west and east. LAČEN-BENEDIČIČ, I., *Ortenburški rudarski red*, p. 17.

[14] LAČEN-BENEDIČIČ, I., *Ortenburški rudarski red*, pp. 17–33; MLINAR, J., *Das Eisenhüttenwesen*, p. 188.

[15] DINKLAGE, Karl: *Kärntens gewerbliche Wirtschaft von der Vorzeit bis zur Gegenwart*. Klagenfurt: J. Leon sen., 1953, pp. 111–112; JOHANN, Elisabeth: *Geschichte der Waldnutzung in Kärnten unter dem Einfluss der Berg-, Hütten-, und Hammerwerke*. Klagenfurt: Geschichtsverein für Kärnten, 1968, p. 22.

[16] JOHANN, E., *Geschichte der Waldnutzung*, p. 23; SPRANDEL, Rolf: *Das Eisengewerbe im Mittelalter*. Stuttgart: Anton Hiersemann, 1968, pp. 322–324.

[17] AT-HHStA, Salzburg, Erzstift, AUR, 1467-1468.2.

[18] MLINAR, Janez: *Urbarji belopeškega gospostva*. Ljubljana: Založba ZRC SAZU, 2018, p. 66.

all the plants (trip hammers, stamping presses for grain threshing, and mills) near Kamnik that used the waterpower of the Kamniška Bistrica River for their operation.[19]

The settlement patterns in ironmaking centres show an awareness that natural resources are exhaustible. In the vast majority of cases, especially in the larger ironmaking areas, two or three smaller centres developed, at some distance from each other, usually following the course of a river upstream or downstream. The main reasons for this were the even distribution of waterpower, the risk of fire, and the increasing use of charcoal. Such patterns can be found especially in the largest ironmaking centres in the Eastern Alps, such as in the Styrian Erzberg area, specifically Innerberg (now Eisenerz) and Vordernberg and several smaller settlements, and in Hüttenberg area (Hüttenberg, Mosinz, Lölling, and Heft), but also in Slovenian territory. In the Jesenice area, smaller centres were established in the mountains above Jesenice, (Stara) Sava, Plavž, and Javornik; in the area of present-day Fusine in Valromana, ironmaking plants were concentrated in three locations along the Rio del Lago Stream (Jezerski potok/Seebach); and in Železniki and Kropa, two larger ironmaking complexes were established along the Selška Sora and Kroparica Rivers.[20] Another characteristic of Styria and Carinthia is the relatively early separation of iron-processing activities from smelting plants. At first, iron processing moved to neighbouring valleys, but increasingly also to more remote areas. Thus, the iron produced in the Erzberg area was largely processed in the valleys at the northern foothills of the Alps, specifically in the border area between Styria and Upper and Lower Austria. Much of the Hüttenberg iron was processed in the valleys of southern Carinthia (e.g., Canal Valley, Rosental, Bad Eisenkappel) and some in Carniola (Fusine in Valromana and Tržič).[21]

The above examples show that in the 14th and most of the 15th centuries, the owners of natural resources did not place significant restrictions on their use for the purpose of iron production. In some cases, however, the restrictions relate to the approximate demarcation of the land given to plant proprietors for their own use. For this, they had to pay dues, which varied from one seigniory to another. In the second half of the 15th century, some seigniories began to introduce new dues for the use of waterpower to raise additional revenue. Towards the end of the 15th century, the situation began to change somewhat, and there appear to be two reasons for that. The first is that many more written sources have survived from this period, and the second is the increase in iron extraction volume, resulting in greater consumption of charcoal. In some places, ironmaking masters had already begun to exploit forests outside their approved areas.

INCREASED USE OF NATURAL RESOURCES IN THE LATE 15TH AND 16TH CENTURIES

To some extent, examples of large-scale deforestation can be traced as far back as the mid-15th century. In a document from 1499, the elderly subjects of the Weissenfels seigniory declared that Andreas Turner, a burgher of the market town of Tarvisio (Trbiž/Tarvis), had already felled all the forest in the vicinity of Ortigara (Koprivnik/Nesseltal) in the mid-15th century[22] for the purpose of operating his two trip hammers in Fusine in Valromana, and then wanted to acquire a new forest holding in the same seigniory from its steward.[23] Further examples of disputes over the use of natural resources for the extraction and processing of iron survive from the turn of the century. These disputes were usually most acute in the border areas between the seigniories of two different landlords, and conflicts also arose between

[19] SI-ARS, AS 1, box 97, Urbar vicedomskega urada za Kranjsko 1496, f. 144.

[20] MITTERAUER, Michael: Produktionsweise, Siedlungsstruktur und Sozialformen im österreichischen Montanwesen des Mittelalters und der frühen Neuzeit. In: *Österreichisches Montanwesen. Produktion, Verteilung, Sozialformen*, ed. Michael Mitterauer. Wien: Verlag für Geschichte und Politik, 1974, pp. 243–244.

[21] PIRCHEGGER, Hans: *Das steirische Eisenwesen bis 1564. Mit einem Ueberblick über das Kärntner Eisenwesen.* Graz: Leykam, 1937, p. 63; MITTERAUER, M., *Produktionsweise*, pp. 245–246.

[22] This part of the text in the document refers to the period when the steward of the Weissenfels Castle was Hans von Zobelsperg, from at least 1447 until 1463. MLINAR, J., *Urbarji*, p. 23.

[23] SI-ARS, AS 1, box 117, Der von Weissenfels Freyhaiten, f. 70–73.

proprietors of ironmaking plants and farmers living nearby. Particularly well documented are the disputes on the Jelovica Plateau between miners and ironmakers from the Selca Valley, who were under the jurisdiction of the Škofja Loka seigniory, which belonged to the Freising Diocese, and those from Kropa, who fell under the jurisdiction of princely Radovljica seigniory.[24]

Similar cases can be identified in the Erzberg area in Upper Styria, which was entirely under the jurisdiction of the territorial prince and had two large ironmaking centres, Innerberg and Vordernberg. Due to the lack of available forests, the masters of Innerberg increasingly encroached on the neighbouring forests owned by the Benedictine monasteries of Admont and Göß. The disputes with Admont in particular could escalate from time to time.[25]

A slightly different situation is indicated by the sources for the Fusine in Valromana area found in Memorial, a collection of documents dating from shortly after 1523, which show that the masters working in the area did not seem to have any problems with wood supplies yet. At the turn of the century, they assarted and cleared new arable land (*neubruchs*) around Fusine, and they also had a common pasture where they grazed their cattle. When wood was harvested for charcoal piles, subjects from the neighbouring settlement of Rateče were allowed to take some of the wood for their own use in return for the payment of a specified amount of forest dues. However, the masters did complain about goat farming, which was causing them difficulties in maintaining the forest area sufficient for their needs.[26]

As can be seen from the above-mentioned documents, the ironmaking masters from Fusine harvested wood for charcoal production from the forest plot that belonged to each plant. The details are given in Memorial, which also states that they only paid dues for this (*Sÿ nemen holtz vnd kol von iren auszaigten Grundtn so zu den hamern gehorn geben annderst nichtz dauon als den zins wieuorstet*).[27] In the following decades, additional charcoal dues (*kholzins*) were introduced, according to the Weissenfels seigniory rent roll from the beginning of the 17th century, which states that proprietors of ironmaking plants had to pay additional dues for the use of forests and the production of charcoal. These were relatively high compared to other dues, amounting to as much as 30 Rhenish *gulden*, while individual subjects who burned charcoal had to pay the seigniory a *gulden* for each charcoal pile.[28]

The Slovenian historian Janez Mlinar suggested that the forest reserves needed for iron production in the western Gorenjska region were sufficient until the end of the Middle Ages. He argued that it was only from the mid-16th century that the region began to experience real change in this respect, pointing to two main reasons: the introduction of technological innovations and the growing number of ironmaking plants. The indirect iron production in blast furnaces was first introduced to the Slovenian territory in the first decades of the 16th century by entrepreneurs and ironmaking masters from Lombardy. Sources refer to these furnaces as Brescian blast furnaces. They were used to produce pig iron in a continuous process. This iron then had to be refined into wrought iron from which semi-finished and finished products could be made. This led to a significant increase in iron production and consequently in charcoal consumption, as substantial quantities of charcoal were also needed in the refining process of pig iron.[29]

As a result, arguments and disputes about the use of wood for ironmaking increased. Mlinar mentions disputes in the Radovna Valley and in the (Slovenski) Javornik and Koroška Bela areas, where in 1559, the peasants from Koroška Bela complained to Daniel Gallenberg, the caretaker of the Bled seigniory, about the excessive use of forests. Ten years later, the proprietors of the ironmaking plants in the Jesenice area complained about Georg Merz, also a Bled seigniory caretaker, for his obstruction of the use of the forest on the Mežakla Plateau. Specifically, Merz wanted to impose dues on every cartload of charcoal taken from that forest.[30] The holder of the Radovljica seigniory, Wolf von Dietrichstein, began

[24] DE-BayHStA, HL 4, fasc. 42/216, no. 156; BLAZNIK, Pavle: *Škofja Loka in loško gospostvo 973–1803*. Škofja Loka: Muzejsko društvo, 1973, pp. 154–155.
[25] PIRCHEGGER, H., *Das steirische Eisenwesen I*, pp. 18–19, 109.
[26] SI-ARS, AS 1, box 117, Memorial zu Weissenfels, f. 92–93.
[27] IBID, f. 92.
[28] MLINAR, J., *Urbarji*, p. 47.
[29] MLINAR, J., *Das Eisenhüttenwesen*, pp. 187–188; OITZL, G., *The Transfer*, pp. 211–215.
[30] MLINAR, J., *Das Eisenhüttenwesen*, p. 189.

to lease the forest belonging to the mining area of Kropa and Kamna Gorica to farmers living outside that area. Complaints about such practice were one of the reasons for Archduke Ferdinand to issue the mining regulations for Kropa, Kamna Gorica, and Kolnica in 1550.[31]

Disputes were also a common occurrence in the Škofja Loka seigniory. Most of them had their roots in the implementation of the princely mining regalia (Bergregal), which excluded the Železniki area, one of the largest ironmaking centres in Carniola, from the jurisdiction of the seigniory which had been in the possession of the Freising Diocese since the High Middle Ages. The seigniory's landlords and stewards, therefore, attempted to restrict the ironmaking masters of Železniki from expanding their forest rights, including through assarting and settling farmers. The mountain areas around Oslica, Žiri, Davča and Martinj Vrh were thus settled as part of the so-called assart colonisation, which began around the mid-16th century and is well documented in the rent rolls from the second half of the century. One of the reasons for this colonisation was the intention of the Bishop of Freising to compensate for the loss of the revenue from the mining and forest regalia (Forstregal) by clearing and settling new land and to create obstacles for any further encroachment on his seigniory.[32]

By the final decades of the 16th century, the problems with charcoal supply became increasingly acute.[33] In 1581, according to Gregor Komar, the senior mining magistrate (Oberbergrichter) for Carniola and Gorizia, the main problems in the operation of ironmaking plants were the increase in the price of charcoal and disputes between ironmaking masters and seigniories over extensive clearing of forests, which were already largely depleted in the vicinity of all plants.[34] In 1584, Komar's successor Hans Holzer arbitrated a dispute between two local ironmaking plant proprietors, Lenart Hren (also known as Leonhard Chrön) and Julius Bucelleni, over the use of wood on the mountains above Jesenice. He ruled that only wood from trees that had already been felled could be used for charcoal, while other trees were to be left standing.[35] Deforestation by the Radovljica seigniory was the subject of several complaints by the senior mining magistrate to the "provincial" *vicedominus* (Landesvizedom), who reported the matter to the Chamber at the end of 1586.[36] In 1594/5, reporting on the failing and already failed ironmaking plants in Carniola and Gorizia, the senior mining magistrate Michael Harrer cited the shortage of iron ore and wood and the rise in charcoal prices as one of the main reasons.[37]

The situation in the neighbouring areas, in major ironmaking centres in Carinthia and Styria, was even worse than in Carniola. In Erzberg in Upper Styria, according to the Austrian historian Hans Pirchegger, problems with charcoal supply began in some places as early as the end of the 14th century. Data for the 15th and 16th centuries also indicate an increase in deforestation. The regulation of the charcoal supply was one of the main reasons for the introduction of mining regulations in 1490, which gave the main ironmaking centres of Innerberg and Vordernberg the right to exploit extensive forests in the surrounding area, while their care was the duty of forest masters. The non-compliance with the regulations and the increasing demand for wood are reflected in the forest and mining regulations issued in the 16th century. In 1539, temporary forest regulations for Styria were issued, and new mining regulations in 1567, when many forests around ironmaking centres had already been almost completely cleared.[38]

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31 MÜLLNER, Alfons: *Geschichte des Eisens in Krain, Görz und Istrien von der Urzeit bis zum Anfänge des XIX. Jahrhunderts.* Wien: Halm und Goldmann, 1909, pp. 281–282.

32 GLOBOČNIK, A., *Geschichtlich-statistischer,* p. 11; BLAZNIK, Pavle: *Kolonizacija Selške doline.* Doctoral dissertation, Univerza Kraljevine Srbov, Hrvatov in Slovencev v Ljubljani, Filozofska fakulteta. Ljubljana: Leonova družba, 1928, pp. 82–97; BLAZNIK, P., *Škofja Loka*, pp. 175–178, 186–198.

33 However, this was not the only problem that the Carniolan iron industry experienced at the time. The second half of the 16th century was also a period of general economic crisis and high cost of living, trade routes shifted due to Ottoman incursions, with poor ore quality and its scarcity in certain areas only further exacerbating the situation. MÜLLNER, A., *Geschichte des Eisens*, pp. 727–728; GESTRIN, Ferdo: *Slovenske dežele in zgodnji kapitalizem.* Ljubljana: Slovenska matica, 1991, pp. 293–298.

34 SI-ARS, AS 1, box. 234, vol. 5, f. 260–267, 431–433.

35 MÜLLNER, A., *Geschichte des Eisens*, p. 388; MLINAR, J., *Das Eisenhüttenwesen*, p. 189.

36 MÜLLNER, Alfons: Das Waldwesen in Krain. Nach archivalischen Quellen. *Argo. Zeitschrift für krainische Landeskunde* 8 (2), 1900, p. 35.

37 SI-ARS, AS 1, box 234, vol. 5, f. 268–271, 276–284.

38 PIRCHEGGER, H., *Das steirische Eisenwesen I*, pp. 18–19, 50–55, 110; PIRCHEGGER, Hans: *Das steirische Eisenwesen von 1564–1625.* Graz: Leykam, 1939, p. 9.

In Carinthia, traces of large-scale deforestation can be traced back to at least the mid-15th century; in 1460, for example, charcoal production was mentioned as one of the reasons for deforestation in the Canal Valley. More serious problems began at least around the mid-16th century when the shortage of charcoal in the Hüttenberg area made it difficult to set up new plants. Several litigations were documented in the 16th century over forest use between neighbourhoods and seigniories, with the Diocese of Bamberg being the most intensively involved. The diocese was involved in the dispute with the Venetian Republic over the border area around the Sella Nevea Pass (Na Žlebeh/Neveasattel), while the dispute with the neighbouring Hüttenberg mining and ironmaking area concerned its forests in the Upper Lavant Valley.[39]

FOREST MANAGEMENT IN THE 16TH CENTURY. MINING AND FOREST REGULATIONS

At the turn of the 15th to the 16th century, the territorial prince began to designate the "black" and "high forests" (Schwarzwald, Hochwald)[40] without a proven private owner as princely property. The greatest value of his treasury was held by the forest that was cleared for mining and metal extraction. The growing consumption of charcoal at this time and the increasing deforestation required more detailed forest management. Informative sources dealing with attempts at regulation and forest management are mining and forest regulations. In the 16th century, the majority of the mining regulations were issued by the territorial prince, also as a result of the expansion or implementation of the mining regalia.[41]

In 1517, Emperor Maximilian I issued the first general mining regulations for the Lower Austrian lands.[42] The regulations established the territorial prince's ownership of black and high forests and watercourses in mining areas, both those that already existed and those that were to be established in the future. In principle, forests owned by monasteries, castles, and towns were exempted, although the territorial prince also allowed the possibility of using these forests for mining and metallurgical activities. The mining magistrate had to discuss this in advance with the owner, who would also receive appropriate compensation. Forests located at least half a mile from mines[43] were not to be cleared unless the mining magistrate permitted the neighbouring subjects (*nachpawrn*) to do so for their own needs.[44]

Mining magistrates had exceptionally extensive rights in the management of forests. They were responsible for protecting forests in mining areas and imposing penalties in unauthorised deforestation cases.[45] In addition to mining pits and metallurgical plants, they also had the right to grant charcoal piles and forest plots (*wald vnd slege*), with the terms of these grants precisely defined in mining regulations. Typically, they were granted to companies (*gesellschaft*),[46] and the grant was valid for a period of one year. Each company could receive only one forest plot at a time, and only after completely clearing it

[39] WIESSNER, Hermann: *Geschichte des Kärntner Bergbaues. III. Teil, Kärntner Eisen*. Klagenfurt: Verlag des Geschichtsvereines für Kärnten, 1953, p. 300; JOHANN, E., *Geschichte der Waldnutzung*, pp. 23, 35–38.

[40] The term "black forest" was used to refer to coniferous forests. The term "high forest", in contrast, defines extensive forest areas in uninhabited mountainous areas, which were intended for normal use but were not part of farmsteads' accessories and also not available for agrarian use. GRITZNER, Max Joseph: *Commentar der Ferdinandnischen Bergordnung vom Jahre 1553 nebst den dieselbe erläuternden späteren Gesetzen und Bergordnungen mit dem Urtexte des Gesetzes in Anhang*. Wien: Baumüllner und Seidel, 1842, p. 10; VALENČIČ, Vlado: Gozdarstvo. In: *Gospodarska in družbena zgodovina Slovencev. Zgodovina agrarnih panog, 1. zvezek. Agrarno gospodarstvo*, eds. Pavle Blaznik et al. Ljubljana: SAZU, 1970, pp. 419–420.

[41] VILFAN, S., *Pravna zgodovina*, pp. 227–228; JOHANN, E., *Geschichte der Waldnutzung*, pp. 24–25; MIHELIČ, Darja: Usoda gozdov na Slovenskem do 16. stoletja. *Ekonomska i ekohistorija* 4, 2008, pp. 31, 34–35.

[42] The term "Lower Austrian lands" refers to the administrative unit of lower-Austrian group of duchies or "provinces" (Land), that was established by the King Maximilian I. It consisted of Upper and Lower Austria, Styria, Carinthia, Carniola, and Gorizia.

[43] Half a (German) mile is just under 4 km. The term "mine" refers to the entire mining areas, which, in addition to mining pits and shafts, included metallurgical plants, mining settlements and accessories - forests, meadows, fields, arable land, etc.

[44] SI-ARS, AS 1073, no. 418, f. 5–5', 16–16'; WAGNER, Thomas: *Corpus Iuris Metallici Recentissimi et Antiquitoris. Sammlung der neuesten und älterer Berggesetze*. Leipzig: Johann Samuel Heinsius, 1791, pp. 33–70.

[45] SI-ARS, AS 1073, no. 418, f. 16'.

[46] A company of holders of interests in mining pits and metallurgical plants. The mining magistrate could also grant plots to individual miners, in accordance with old customs or customary mining law. SI-ARS, AS 1073, no. 418, f. 17.

could they receive a new one.[47] The granted plots could not be transferred to other proprietors.[48] The felling of trees had to be carried out from higher to lower elevations, and trees of all sizes had to be cut out (*vom obristen bitz zum vndristen gros vnd clain slahen*). Each proprietor had to cut down the trees at their end, in order to avoid work accidents and disputes with other proprietors. Logging was not to be done under compulsion and could be performed by farmers from the surrounding area and "foreign" loggers (*frembd holtzknecht*). The forest had to be kept groomed, and felled trees had to be removed; otherwise, the magistrate had the right to withdraw the forest from the proprietor.[49] The-princely forest masters, seigniory holders and stewards, and other officials must have relatively often interfered with the administration of forests in mining areas, the imposition of fines for offences, and unauthorised deforestation. The document explicitly prohibits such actions.[50]

The mining regulations would also address the management of other natural resources. Miners and all those subject to the jurisdiction of the mining magistrate (*pergwerch vnderworfn*) were allowed to graze their livestock on common meadows, by agreement and after consultation with the seigniory and the mining or territorial magistrate (Landrichter). Each miner was given a plot of land on the community's land to build a house, while the dues had to be paid to the seigniory. Hunting and fishing were forbidden without specific permission from the territorial prince or the landlord, with the mining magistrate responsible for overseeing compliance.[51]

The next general princely mining regulations for all Lower Austrian lands were issued by Archduke Ferdinand in 1553. Many of its articles are similar to those of 1517, indicating that their provisions were likely not fully complied with. The high and black forests and watercourses were defined as princely or sovereign property in introductory articles.[52] The granting of forest plots, as well as mining pits and metallurgical facilities, remained with the mining magistrate. The exceptions for using forest in the mining area and its immediate vicinity (half a mile from the mine) also remained unchanged.[53]

The mining regulations of 1553 did, however, introduce more precise guidelines for logging. Tree trunks had to be cut as close to the ground as possible, with the maximum allowable height of the stump at two spans (*daumelle*). The provision in the same article that the tops of trees should also be used indicates the economic use of wood. The provision that felled trees were preferably used for making charcoal, roasting ore, and supporting mine tunnels, pits, and shafts suggests potential difficulties in securing an adequate supply of charcoal. The problem of charcoal prices is indicated by the provision that magistrates were required, with the assistance of the sworn miners and landowners, to ensure proper transport, delivery, and pricing of wood. The territorial prince wanted to standardise the measure for charcoal across Lower Austrian mining areas. The selected basis was the size of a charcoal sack from the mines near Schwaz in Tyrol (*schwatzer-sack*), seven feet long and four feet wide. Wagons used for transporting charcoal (*kohlkrippen*) had to be adapted to this size.[54] With regard to water management, a notable provision prohibited alterations to water flows without the knowledge of smelting masters, plant proprietors and plant workers.[55]

The article defining the selection of contractors for logging and transporting (of ore, wood, charcoal, and other supplies) is formulated slightly differently than in the regulation of 1517. Initially, only subjects

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47 Upon the granting of a plot, the recipient was required to pay three kreutzers to the mining magistrate and one kreutzer to the mining scribe.

48 However, it was permitted to transfer plots to individuals who used forest solely for charcoal production and its subsequent sale. These individuals could also receive only one plot, which was limited in size, and were required to contribute dues to the chamber from the sale of charcoal (*fron vnd wexl*). SI-ARS, AS 1073, no. 418, f. 17'.

49 SI-ARS, AS 1073, no. 418, f. 6', 17–18'.

50 IBID, f. 17.

51 IBID, f. 6.

52 GRITZNER, M., J., *Commentar*, p. 9; GALLOR, Gernot: Das rechtliche Spannungsfeld zwischen Nutzung und Schutz des Waldes in der Neuzeit. In: *Man, Nature and Environment between the Northern Adriatic and the Eastern Alps in Premodern Times*, eds. Peter Štih, Žiga Zwitter. Ljubljana: Znanstvena založba Filozofske fakultete, 2014, p. 365.

53 GRITZNER, M., J., *Commentar*, pp. 32, 122–136.

54 IBID, pp. 134–137.

55 IBID, p. 199.

from the surrounding area could be hired for this purpose, while foreign workers could not be employed without sufficient justification, such as if subjects demanded excessive wages.[56] This raises the question of whether the makers of the document sought to avoid higher labour costs for the mines or whether the purpose of this provision was to employ as many as possible of the subjects from the area who could not support themselves by working on the farms.

Mining activities in Carniola in the 16th century were specified in detail in two mining regulations. The regulations for Kropa, Kamna Gorica, and Kolnica, issued by Archduke Ferdinand in 1550, three years prior to the general mining regulations, had local authority. They contained relatively few provisions regarding the use of forests, and these did not introduce any significant innovations. Plant proprietors and other residents within a mining area could use the forests within that mining area for their personal needs (to repair plant facilities, outbuildings and residential dwellings) only after agreement with the holder of the seigniory and the mining magistrate. In return, they had to pay an additional dues, separate from the common dues for ironmaking plants.[57] The latter included the payment of the right to use wood for charcoal production, paid by the holders of shares in the plants.[58] In this area, too, the mining magistrate was responsible for protecting the forest. Assarting was forbidden, and a violation of this prohibition carried a severe physical penalty (*schwerer leibs straf*).[59] The provision mandating safety precautions when felling trees also speaks to a significant number of injuries at work.[60]

The mining regulations for Carniola and Gorizia, issued by Archduke Charles II in 1575, contain considerably more provisions regarding the use of forests. As mentioned above, the problems caused by charcoal shortage were one of the reasons that the regulations were drafted and issued in the first place.[61] The articles are broadly similar in content to those of the mining regulations of 1553. High and black forests, as well as watercourses, were again designated as the property of the territorial prince, and the responsibility for forest management in mining areas fell under the jurisdiction of the senior mining magistrate for Carniola and Gorizia and mining (sub)magistrates in individual areas.[62]

The document reveals several changes compared to older mining regulations. The territorial prince reserved the right to grant forest plots and ore deposits, mines, and metallurgical plants. When there was a shortage of charcoal, and at the request of plant proprietors and the senior mining magistrate, as well as with the approval of the Lower Austrian Chamber Council, metallurgical plants could be relocated to nearby forests.[63] Notably, there is a provision specifying careful examination of ore to avoid unnecessary consumption of charcoal (*noch das Khol zu vnnutz verbrennt*) and payment for ore transport.[64] Apart from ensuring a moderate use of charcoal, this provision could also have arisen from the goal to maximise the Chamber's profits and prevent the production of inferior quality goods, as poorly examined ore could adversely affect the quality of produced iron.

The use of forests was elaborated in one of the final articles. The obligation to clear out entire plots remained, but a provision was added, stipulating that for erosion protection some trees must be left standing in exposed areas (*allein zusaumb Beümb etlich groß Hayer auff der hohen Ridlen oder Eggen zubeschüttung stehen lassen, die soll niemandt abhagkhen*). Particular attention was given to preserving young trees, aiming for them to grow to full height to be better suitable for subsequent use in charcoal making. In the case of unauthorised deforestation, a fine of 12 kreutzers per tree trunk was imposed. The provisions for logging contractors followed those of the mining regulations from 1517, whereby

56 IBID, pp. 136–137.
57 AT-OeStA, FHKA, MBW, no. 96, f. 153'–154.
58 IBID, f. 149'–150.
59 IBID, f. 154.
60 IBID, f. 157'.
61 SI-ARS, AS 1, box. 234, vol. 7; MÜLLNER, A., *Geschichte des Eisens*, pp. 136–138.
62 SI-ARS, AS 1073, no. 420, f. 5–5'. Mining magistrates supervised logging and charcoal-making while ensuring the conservation of forests. This was understood to mean the prevention and sanctioning of assarting, burning of forests, felling of young trees and goat-herding. SI-ARS, AS 1073, no. 420, f. 26'–27.
63 SI-ARS, AS 1073, no. 420, f. 7'.
64 IBID, f. 14.

landowners could assign this work to anyone they desired but had to ensure equal payment for both foreign and local workers. Disputes between workers were relatively frequent, as were damages inflicted on individual forest plots, charcoal piles, and wooden slides, which might suggest problems arising from wood shortages and, by extension, charcoal.[65]

The Chamber also attempted to introduce a uniform measure for charcoal in Carniola and Gorizia, with the sack having to contain six Ljubljana *Stars*.[66] This measure was clearly different than the one from Schwaz, suggesting that the attempt to introduce a uniform measure across all mining areas in the Lower Austrian lands had likely failed relatively early. A prototype measure was sent to each mining area by the Carniolan "provincial" *vicedominus*, and one prototype was kept in the office of the senior mining magistrate. The measure was used in the manufacture of transport wagons, which had to be marked with a shield bearing the coat of arms of the Duchy of Carniola.[67]

To an even greater extent and with more precision than mining regulations, forest management in the 16th century was governed by forest regulations issued only for individual lands or larger seigniories. In the context of iron mining and processing, mention should be made of the so-called temporary Styrian forest regulations of 1539, which revealed serious problems with securing sufficient charcoal quantities for the local iron industry. A considerable number of its provisions are dedicated to preserving forests for the purpose of wood consumption by the mines in the Erzberg area and the ironmaking plants in the wider area. One of the introductory articles even mentions the need to preserve wood for the plants to be able to continue their operations, as their collapse would cause irreparable damage to the duchy and the empire.[68] Extensive forest areas were intended primarily for charcoal production, with the ban on the use of the forest for agrarian activities and as construction material in force. The oversight duty fell to a special administrator, the forest master.[69]

Some provisions are notable for indicating the careful management of wood consumption. Fences had to be built only from branches, and before trees were felled, they had to reach a certain height, at least one and a half men. The construction of new sawmills had to be approved by the seigniory, and existing ones could be dismantled if they posed a threat to ironmaking operations. Throughout Upper Styria, goat farming was only allowed in fields but was once again forbidden in forests. Several provisions referred to the regulation or restriction of mountain pastures. Newer pastures located too close to forests had to be abandoned, and the number of livestock was also restricted. Pastures owned by ironmaking masters also had to be abandoned if they were renting them out in exchange for the payment of dues.[70]

In Carinthia, the first patent related to forest conservation was issued in 1550. Goat farming was prohibited, as was assarting and deforestation without the landlord's knowledge and consent. Seigniories also imposed restrictions on the use of forests. The Bamberg Diocese issued forest regulations for all its possessions in Carinthia as early as 1550 and two further regulations in 1584 for the Canal Valley and Bad Bleiberg mining area.[71] The forest regulations for Canal Valley, issued in 1584 by Bishop Ernst Mengersdorf of Bamberg, comprised 41 articles and their issuance was closely linked to the use of forest for iron-processing operations in the valley and in the lead and zinc mining area of Cave del Predil (Rabelj/Raibl).[72] The responsibility for the diocese's forests rested with the forest master, who had to

65 IBID, f. 27–27'.

66 The Ljubljana *Star*, a unit of measurement established in the years after 1569, contained about 106 litres. Accordingly, a sack of charcoal would hold about 636 litres, or 0.636 m³. VILFAN, Sergij: Prispevki k zgodovini mer na Slovenskem s posebnim ozirom na ljubljansko mero (16.–19. stoletje). *Zgodovinski časopis* 8, 1954, pp. 42–49.

67 SI-ARS, AS 1073, no. 420, f. 27'–28.

68 ANKO, Boštjan (ed.): *Začasni štajerski gozdni red 1539*. Viri za zgodovino gozda in gozdarstva na Slovenskem 3. Ljubljana: Biotehniška fakulteta, 1987, pp. 15–19, 49.

69 MIHELIČ, D., *Usoda gozdov*, pp. 35–38; ANKO, B., *Začasni štajerski gozdni red*, pp. 23–58.

70 ANKO, B., *Začasni štajerski gozdni red*, pp. 29–60.

71 JOHANN, E., *Geschichte der Waldnutzung*, pp. 39–43; MIHELIČ, D., *Usoda gozdov*, pp. 40–46.

72 The forest regulations for the Bleiberg mining area are a synthesis of Canal Valley forest regulations and have 21 articles. Both were issued by the Bishop of Bamberg on 22 December 1584 in Wolfsberg and were drawn up by the diocesan inquiry commission which had previously examined the forest conditions. ANKO, Boštjan (ed.): *Bamberška gozdna reda za Kanalsko dolino in bleiberški okoliš*. Viri za

inspect them at least once a year. If necessary, the Bamberg *vicedominus* in Carinthia and the magistrates of the market towns of Tarvisio and Malborghetto (Naborjet/Malborgeth) were obliged to assist him.[73]

Excessive deforestation in the Canal Valley began to threaten the supply of charcoal to plants and wood needed in building construction and heating. Ironworkers and farmers had apparently appropriated some forest plots, and the regulation stipulated that all plots without a granting certificate had to be returned. Coniferous forests could be granted by the forest master only with the consent of the *vicedominus* and the diocesan advocate (*Vogt*). The same applied to the granting of forests to ironmaking masters for the purpose of charcoal-making. In return, masters had to pay a certain fee. The export of wood to Italian lands was restricted and was overseen by the forest master, who charged a fee of four kreutzers for each log. Like in other regions, assarting and goat farming were strictly limited. These regulations also contain detailed instructions for tree felling, such as the maximum allowable stump height, a ban on winter felling, and the clearing of branches. The forest master was also responsible for checking the adequacy of charcoal piles, the conclusion of contracts between ironmaking masters and loggers, and the eligibility of individual foreign workers, who were required to carry a travel document (*paßport*).[74]

CHARCOAL CONSUMPTION IN IRONMAKING. AN ATTEMPT AT CALCULATION

What was the actual consumption of charcoal and consequently wood in the iron industry in the 15th and 16th centuries, and how much forest had to be cleared to cover this consumption? To answer this question, the ratio between the weight or volume of wood and the amount of charcoal obtained from that volume first has to be determined. Then, the amount of charcoal used to extract a given quantity of iron and to process it into semi-finished products has to be established. Furthermore, knowledge of the type of material extracted and processed is also important, as different quantities of charcoal were used for different types of iron. An estimate of the deforested area is contingent on additional variables, leaving the validity of the final result on rather shaky ground.[75]

With regard to the ratio of wood to charcoal, two different types of information are available, both relatively similar to each other. Slovenian historian Darja Mihelič suggests that the original volume of wood is halved during charcoal burning, and its mass is reduced to a quarter.[76] Czech archaeometallurgist Radomír Pleiner, in contrast, maintains that a cubic metre of dry wood weighing about 600 kg could yield 55% of its volume (depending on the type of wood), and between 16 and 20% of its weight to charcoal.[77]

Estimates of the amount of charcoal needed to obtain a specific amount of iron are more varied. Mihelič provides a relatively general figure with a fairly broad range, saying that in the 16th century, to produce a tonne of pig iron, between 15 and 35 m³ of charcoal were needed, equivalent to approximately 30 to 70 m³ of wood.[78] Pleiner offers more precise estimates, suggesting that producing one weight unit of iron required between eight and ten units of charcoal, possibly more. To produce a higher quality material, such as harder iron or steel,[79] about half as much additional charcoal was needed. For example, obtaining 100 kg of steel required about 1500 kg of charcoal.[80] Therefore, producing a tonne of wrought

zgodovino gozda in gozdarstva na Slovenskem 4. Ljubljana: Biotehniška fakulteta, 1987, pp. 65–67, 97–99.

73 ANKO, B., *Bamberška gozdna reda*, pp. 5–14, 71.

74 ANKO, B., *Bamberška gozdna reda*, pp. 8–83.

75 On the complexity of such calculations, cf. PLEINER, Radomir: *Iron in Archaeology: the European Bloomery Smelters*. Praha: Archeologicky ustav AV ČR, 2000, p. 126.

76 MIHELIČ, D., *Usoda gozdov*, pp. 30–31.

77 PLEINER, R., *Iron in Archaeology*, p. 118.

78 MIHELIČ, D., *Usoda gozdov*, pp. 30–31.

79 The term "steel" here is understood to have the same meaning as in contemporary sources or in the period under consideration. "Iron" (Eisen) was generally used to refer to soft wrought iron, while hard iron was referred to as "steel" (Stahl).

80 PLEINER, R., *Iron in Archaeology*, p. 118.

iron would require about 33 m³ of charcoal, and a tonne of steel would require about 50 m³ of charcoal.[81] These figures are slightly higher than those of Mihelič, who provides a specific figure for pig iron.

In the early 1950s, upon the discovery of a Late Middle Age smelting furnace near Kropa (the Slovenian Furnace in Dno pri Kropi archaeological site), the Slovenian metallurgist Ciril Rekar made an estimate of a lump of iron produced in this furnace. It was believed to be about 200 kg, which would require about 600 kg of charcoal,[82] considerably less than the estimates by Mihelič and Pleiner presented above.

Estimates of charcoal consumption in the late medieval iron industry are also provided by research conducted in the United Kingdom. In the southern part of Eryri (Snowdonia) in Wales, ironworking activity has been archaeologically proven at the Llwyn Du site through radiocarbon analysis and dendrochronology, spanning between the late 14th and early 15th centuries. Between 200 and 250 tonnes of slag are thought to have been produced on the site. This was a case of low-volume production, with the use of waterpower to drive the bellows of the smelting furnace questionable, since calculations suggest that in one smelting process, an iron bloom of about 8.5 kg was produced. In one year, approximately 175 tonnes of wood were used in 280 smelting processes.[83] Taking into account wood density (mainly oak and birch), this would imply that 49 m³ of charcoal was used to obtain 1000 kg of iron, which is quite substantial.

Slovenian historian Vlado Valenčič provides information that in the 16th century, obtaining 50 tonnes of pig iron required 5,000 m³ of wood or about 2,500 m³ of charcoal. One tonne of pig iron would therefore require around 50 m³ of charcoal.[84] This is considerably more than the information provided by Austrian historians Hermann Wiessner and Elisabeth Johann, based on a written source from Hüttenberg dating from 1560. According to that source, obtaining an iron bloom weighing about 616 kg would require about 8.9 m³ of charcoal,[85] or 14.45 m³ of charcoal per tonne of iron, comparable to the lower limit of the estimate offered by Mihelič. In the neighbouring Lölling, however, about 11.9 m³ of charcoal were used to obtain an iron bloom (although Johann does not state whether it had the same mass as in Hüttenberg), suggesting around 19.3 m³ for a tonne of iron. Johann points out that charcoal consumption was influenced by several factors, including the specifics of each smelting furnace, the know-how, and the quality of ore and charcoal. The charcoal consumption was significantly higher in pig iron processing, with around 35.4 m³ of charcoal reportedly used to produce 1000 kg of wrought iron.[86]

The introduction of the new technology for the extraction of pig iron in the indirect process in blast furnaces has not in itself led to a substantial increase in charcoal consumption.[87] Data for the blast fur-

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81 The conversion from mass to volume is based on charcoal density, which varies according to the tree species used in the charcoal-making process. Charcoal was usually made from whichever tree species was available, sometimes also from a combination of different tree species. Charcoal from deciduous trees, such as oak and beech, was more suitable for smelting furnaces, where higher temperatures were needed. According to the descriptions in Valvasor's *Glory of the Duchy of Carniola,* beech was the predominant tree growing in Gorenjska at this time, but its presence declined significantly in the following centuries due to the expansion of conifers, driven in part by deforestation for the purposes of the iron industry. The typical density of wood charcoal is said to range between 180 and 220 kg/m³, while other data suggests densities between 260 (spruce) and 380 kg/m³ (birch), with beech charcoal having an even slightly higher density. In this paper, a wood charcoal density of 300 kg/m³ was used for the conversion from mass to volume or vice versa. VALENČIČ, V., *Gozdarstvo*, p. 425; PLEINER, R., *Iron in Archaeology*, p. 116; https://energypedia.info/wiki/Charcoal_Production ; https://fillenergi.ee/product/wood-charcoal/.

82 REKAR, Ciril: Slovenska peč v Kropi. *Slovenska peč. Vodnik po zgodovinskem plavžu v Dnu nad Kropo*. Ljubljana: Nova proizvodnja, 1954, pp. 67–68.

83 CREW, Peter; MIGHALL, Tim: The Fuel Supply and Woodland Management at a 14th Century Bloomery in Snowdonia. A Multi-disciplinary Approach. In: *The World of Iron*, eds. Jane Humphris, Thilo Rehren. London: Archetype Publications, 2013, pp. 473, 481.

84 VALENČIČ, V., *Gozdarstvo*, pp. 441–442.

85 WIESSNER, H., *Geschichte des Kärntner Bergbaues*, p. 39; JOHANN, E., *Geschichte der Waldnutzung*, p. 27. The information in the source is expressed in buckets (*Schaff*). Accordingly, 18 buckets of charcoal were required to obtain an iron bloom. A bucket would hold 15.5 cubic feet or 0.496 m³ (the volume of a cubic foot was about 32 dm³).

86 WIESSNER, H., *Geschichte des Kärntner Bergbaues*, pp. 39–40; JOHANN, E., *Geschichte der Waldnutzung*, pp. 27–28. Although it may initially appear that charcoal consumption during iron processing was lower, it is important to consider that the processing was carried out at an open forge hearth, while ore reduction took place in the enclosed space of a smelting furnace.

87 Johann mentions that charcoal consumption decreased while the amount of obtained iron remained the same, although this contradicts the data presented later. This interpretation is possibly based on the fact that with the indirect procedure of pig iron extraction the

nace at Urtl from 1580 show that to obtain one miliarium[88] of pig iron, between 10.9 and 12.9 m³ of charcoal were used, or between 19.5 and 23 m³ of charcoal per tonne of pig iron. The increase in charcoal consumption with the introduction of the new technology is mainly due to two factors. Blast furnaces were able to produce larger quantities of iron, though not in the form of bloom but rather as pig iron. Because pig iron contained too much carbon, it had to be first processed in finery hearths in order to obtain wrought iron, which required additional quantities of charcoal. Only then could the obtained iron be forged into wrought iron or steel semi-finished products.[89] No data were found on charcoal consumption for the conversion of pig iron into wrought iron and steel in the 16th century, but information from the mid-17th century is available for Krems in Carinthia. Around 19.5 m³ of charcoal was used to obtain 1000 kg of pig iron, 29.3 m³ to convert it into the same amount of wrought iron and about 46.25 m³ of charcoal to convert it into steel.[90] The reasons for the lower charcoal consumption during pig iron processing in this case could vary from inaccurate calculations to a more sophisticated pig iron-processing technology.

Type of the material	Charcoal volume [m³]	Place and period
Pig iron	15 - 35	
Steel	50	
Wrought iron	33	
Bloom	10	Kropa, Late Middle Ages
Bloom	39,2	Llwyn Du, ca. 1400
Bloom	49	Llwyn Du, ca. 1400
Pig iron	50	Carniola, 16th c.
Bloom	14,45	Hüttenberg, 1560
Bloom	19,3	Lölling, 1560
Wrought iron	35,4	Hüttenberg, 1560
Pig iron	19,5 - 23	Urtl, 1580
Pig iron	18,9	Carinthia, 17th c.
Bloom	26,8	Carinthia, 17th to 18th c.
Pig iron	17,7 - 22,1	Urtl, 2nd half of the 17th c.
Pig iron	19,5	Krems, 1648
Wrought iron	29,3	Krems, 1648
Steel	46,25	Krems, 1648

Tab. 1. *Quantitative data on the average charcoal amount needed to obtain 1000 kg of iron*

According to data from 1563, in the Hüttenberg area, 55,440 m³ of charcoal were used to produce iron in 22 smelting furnaces, and a further 48,600 m³ of charcoal to process iron in nine trip hammers.[91] In total, around 102,672 m³ of charcoal were used during that year, which would have amounted to just over 205,000 m³ of wood. To illustrate the situation in the Slovenian territory, similar calculations of the annual charcoal and wood consumption could be made for the Jesenice ironmaking area and the entire Carniola and Gorizia regions, based on the production volume data preserved for these areas from 1581. The figures presented in the source are likely not entirely accurate, as they only estimate the export volume from individual ironmaking areas in Carniola and Gorizia. The total export volume was estimated at 1965 miliaria of iron (1100.4 tonnes) in various forms, ranging from pig iron to finished products such as nails and horseshoes. Adding to this calculation, the production volume in Fusine in Valromana, which was not included in the source, and of various smaller processing plants, and assuming that a certain portion of the obtained iron remained in the country, the total iron production could be estimated at up to about 3000 miliaria (1680 tonnes).[92]

process is a continuous one, meaning that furnaces did not have to be heated before each smelting.

88 One miliarium consisted of 1,000 Viennese pounds, in total approximately 560 kg.

89 JOHANN, E., *Geschichte der Waldnutzung*, p. 30; PLEINER, R., *Iron in Archaeology*, p. 284.

90 JOHANN, E., *Geschichte der Waldnutzung*, pp. 81–82; WIESSNER, Hermann: Zur Geschichte des Eisenbergbaues in Krems. *Carinthia I* 139, 1949, p. 321.

91 WIESSNER, H., *Geschichte des Kärntner Bergbaues*, p. 42; JOHANN, E., *Geschichte der Waldnutzung*, p. 28.

92 SI-ARS, AS 1, box 234, vol. 9, f. 214–216; MÜLLNER, A., *Geschichte des Eisens*, pp. 477–478; OITZL, Gašper: *Družbene in gospodarske posledice železarjenja na Slovenskem v poznem srednjem veku*. Doctoral dissertation, Ljubljana: Filozofska fakulteta, 2021, pp. 403–404.

Taking into account that iron waste during processing stood at 25%[93] and the fact that the facilities in Fusine (and some others) purchased at least part of their iron in Carinthia, it could be assumed that in Carniola and Gorizia at the time about 3,500 miliaria (1960 tonnes) of iron were produced in smelting furnaces and blast furnaces, in approximately equal proportions. For an estimate of the charcoal consumption to obtain a tonne of iron in the smelting furnace in the form of a bloom, comparison calculations offered by Rekar and Johann (15 m³ of charcoal) can be applied, and for the same amount of pig iron an estimate close to the calculations of Mihelič and Johann (20 m³ of charcoal). To obtain about 1,750 miliaria of iron (980 tonnes) in smelting furnaces and the same volume in blast furnaces, a total of about 34,300 m³ of charcoal, or about 75,000 m³ of wood, would be used.

To calculate charcoal consumption for the processing of iron, the estimates offered by Johann and Pleiner for wrought iron (35 m³ of charcoal per 1000 kg) and steel (50 m³ of charcoal per 1000 kg) can be applied. For the processing of pig iron, slightly higher figures can be considered, as suggested by Johann in the case of Krems, namely 45 m³ of charcoal per 1000 kg of wrought iron and 60 m³ of charcoal per 1000 kg of steel. For finished products, which were mainly nails, the estimate by Jože Gašperšič regarding the annual charcoal consumption in an individual nail forge hearth (11.7 m³ of charcoal) will be used.[94] Exports of finished products accounted for about one third of total exports, and we have estimated the share of semi-finished steel products at 15%, taking into account that all steel was obtained from pig iron. In the case of wrought iron semi-finished products, we estimated that half was obtained from blooms and the other half from pig iron. Under these assumptions, the annual iron processing in Carniola and Gorizia would have consumed an additional 71,536 m³ of charcoal, thus totalling 105,836 m³ of charcoal or about 210,000 m³ of wood[95].

The source under consideration shows that in 1581, the volume of exports from ironmaking centres in the Jesenice area (Sava, Plavž, and Javornik) was estimated at 440 miliaria of iron, both in the form of semi-finished wrought iron and steel, while blast furnaces produced pig iron.[96] It is a fair assumption that the total production was slightly higher, as some semi-finished products and pig iron were likely sold within the Carniola. The total production would therefore amount to around 500 miliaria (280 tonnes) of iron, or 625 miliaria (350 tonnes) of pig iron when taking into account the waste during processing. To obtain pig iron, 7,000 m³ of charcoal would be used, and to convert it into semi-finished wrought iron and steel products in roughly equal proportions another 14,700 m³ of charcoal would be needed. The total amount of charcoal needed for such iron production in the Jesenice area would therefore be around 21,700 m³, representing around 43,000 m³ of wood.

Using the above data to estimate the extent of deforestation, we find ourselves on much shakier ground. In addition to the already used written sources and more or less solid variables and assumptions, the information on the "forest density", or the so-called forest growing stock, must be applied. This is expressed as the number of cubic metres of wood per hectare of land area and is likely to vary according to tree species, tree thickness, terrain, and various other geographical and geological factors.

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93 Cf. OITZL, G., *Družbene in gospodarske*, pp. 396–397.

94 Charcoal was used to heat the hearths during the processing of iron into semi-finished products and during the forging of finished products. The amount of charcoal used in a hearth of a nail forge depended on various factors, such as the size of nails; in the case of smaller nails, around 2,500 kg of charcoal were used annually, and a figure from the end of the 19th century goes as high as 6,000 kg of charcoal used in a hearth of a nail forge. For this calculation, the approximate median estimate of 3,500 kg was used, which is equivalent to 11.7 m³ at a charcoal density of 300 kg/m³. In 1579, there were 16 nail forges in Kropa, Kamna Gorica, and Kolnica. The exports from Železniki equalled those from Kropa and Kamna Gorica, so the same number of nail forges was considered for Železniki as for the above-mentioned settlements (13). Each forge had several hearths in operation, so an approximate median estimate of 4 hearths was applied to the calculation. Since nails were also exported from other places, the number of forges determined for the purpose of the calculation was set at 40. SI-ARS, AS 173, Urbar gospostva Radovljica 1579, f. 230–274; GAŠPERŠIČ, Jože: *Vigenjc. Vodnik po zgodovinskih žebljarskih kovačnicah v Kamni Gorici, Kolnici, Kropi in Železnikih*. Ljubljana: Tehniški muzej Slovenije, 1956, p. 42.

95 Slovenian historian Jože Šorn estimated annual consumption of wood for ironmaking in the end of the 17th century at around 150.000 m³. ŠORN, Jože: Eisengewerbe in Jugoslawien von 1500-1650. In: *Schwerpunkte der Eisengewinnung und Eisenverarbeitung in Europa 1500-1650*, ed. Hermann Kellenbenz. Kölner Kolloquien, 2. Köln, Wien: Böhlau, 1974, p. 340.

96 SI-ARS, AS 1, box. 234, vol. 9, f. 214–215; MÜLLNER, A., *Geschichte des Eisens*, p. 477.

The following estimates of the extent of deforested areas in the late 16th century should therefore serve only as a very rough estimate.

The literature provides a wide range of information on the forest growing stock, ranging from 70 m³ per hectare to as much as 1368 m³ per hectare.[97] British archaeologist Henry Cleere states that the forest growing stock of oak and birch forests in Great Britain amounted to 1200 m³ per hectare. To calculate deforestation in Roman-era ironworking in Britain, he used the factor of 400 m³ per hectare, partly because charcoal was mainly produced from tree branches.[98] In the territory of the present-day Republic of Slovenia, the average forest growing stock in 2022 stood at 303.5 m³ per hectare. It was slightly higher in the forests where most ironmaking centres once operated. In the GG Bled and GG Kranj[99] areas, the forest growing stock amounted to 334.9 m³ per hectare and 367.6 m³ per hectare, respectively. However, it is important to note that the forest structure about five centuries ago was significantly different than it is today when conifers are the dominant forest type in both areas (71.3% in GG Bled and 64.1% in GG Kranj).[100] Although the data on the forest growing stock or at least forest coverage of the Slovenian territory in the late 16th century is not available, after the conclusion of medieval colonisation, forested areas are assumed to have covered about two-fifths of the Slovenian ethnic area.[101] The earliest precise data are from 1773, when the forest coverage of the Slovenian territory was similar, amounting to 35%. This did not change significantly over the following century (37% in 1875), with the largest increase starting from 1947 onwards (43%), and in 2022, 58% of the surface of the Republic of Slovenia was covered by forest. At least in the second half of the 20th century, the increase in forest areas went hand in hand with the increase in forest growing stock which in 1947 still stood at 126 m³ per hectare.[102]

Assuming that the forest growing stock was at least partially correlated with forest coverage, and considering that forest management in the 16th century was significantly less regulated than in the second half of the 20th century, an estimate of the forest growing stock in the period under consideration could be set at 100 m³ per hectare.[103] To counterbalance this estimate of forest consumption, the figure for forest growing stock of 400 m³ per hectare will also be applied, as it is closer to the current situation and has also been used in some studies abroad.[104] Taking into account the lower forest growing stock estimate and the anticipated wood consumption for the iron industry in Carniola and Gorizia (210,000 m³ of timber), 2,100 ha of forest area would have to be completely cleared for this purpose. Taking into account the higher forest growing stock estimate, 525 ha of forest area would have to be cleared.

Place	Period	Estimate of annual wood consumption [m³]	Estimate of annually deforested area [ha]
Carniola	1581	210.000	525 - 2100
Jesenice	1581	43.000	107,5 - 430

Tab. 2. *Estimation of deforested areas*

97 SPRANDEL, R., *Das Eisengewerbe*, p. 317.

98 CLEERE, Henry: *The Iron Industry of Roman Britain.* 1981,, p. 122. The mining and forest regulations under discussion offer no evidence of the (predominant) use of branches in charcoal-burning. Given the extensive charcoal consumption, it is probably difficult to imagine that only the branches from felled trees were used for charcoal production.

99 "GG" stands for Forest Management Company.

100 Slovenia Forest Service Report, p. 7.

101 MIHELIČ, Darja: Kratek prerez zgodovine gozda in gozdarstva na Slovenskem – I. In: *Pomen zgodovinske perspektive v gozdarstvu*, ed. Boštjan Anko. Ljubljana: VTOZD za gozdarstvo, Biotehniška fakulteta, Univerza Edvarda Kardelja, 1985, p. 64. It is difficult to draw any reasonable conclusions about the extent of forest cover at the end of the 16th century. It most likely ranged between that of the 18th century and today's, probably closer to the former. Compared to today's situation, significantly larger areas were occupied by agricultural land, but significantly less forest was cleared because of mining and metallurgy than in 1773 and 1875.

102 Slovenia Forest Service Report, p. 5; PESERL, Andreja; BENCIK, Andrej: Gozdnatost Slovenije v obdobju 1773 do 2005. *Les = Wood* 61 (2), 2009, pp. 63–66.

103 Cf. SPRANDEL, R., *Das Eisengewerbe*, p. 317.

104 Cf. CLEERE, H: *The Iron Industry*, p. 122.

Because deforestation for ironmaking purposes in individual locations in these two regions varied in intensity, mainly depending on the proximity of ironmaking centres, a more relevant estimate for illustrating the impact of iron industry on forests is for a larger individual ironmaking area, such as the Jesenice area, where the estimated annual wood consumption stood at around 43,000 m³. In this case, the annual deforestation rate would be between 430 and 107.5 ha, representing a relatively significant deforestation.

Although the resulting estimate may be based on very shaky ground, it is meaningful enough to indicate relatively intensive human intervention in the natural surroundings due to ironmaking activities at least as early as the second half of the 16th century, as confirmed by contemporary written sources. An interesting comparison is offered by the estimate of the deforested land in the Weald area in southeast England in the 2nd and 3rd centuries AD, during the operation of one of the major ironmaking centres in the Roman Empire. For this estimate, the forest growing stock at 400 m³ per hectare was used. The final result showed that during the period of most intensive ironmaking between 120 and 240 AD, between 2 and 3.5 km² of forest were cleared each year.[105]

CONCLUSION

The earliest written sources demonstrating intensive ironworking in Slovenia show that proprietors of ironmaking facilities were required to obtain permission from their respective seigniories to use forests. In return, they paid certain dues, sometimes included in a collective amount but could also be levied as additional, possibly quite high dues. Towards the end of the 15th century, seigniories began to impose additional dues for the use of waterpower, and in the 16th century, additional charges for the use of forests and charcoal production, "charcoal dues", became more widespread. From the turn of the 15th century, disputes over the use of forests for ironmaking became increasingly common, arising both among individual ironmaking communities and between ironworkers and the administration of the seigniory in which they operated. The disputes often resulted due to the implementation of the princely mining regalia and the ownership of forests in mining areas and in their immediate vicinity.

The 16th-century princely mining regulations clearly demonstrate a growing concern for the management and conservation of forests. The first general mining regulations for the Lower Austrian lands, dating from 1517, already contained several provisions relating to forest ownership, the allocation of forest plots and forest management. The subsequent regulations from 1553 introduced some innovations in the felling of trees, the use of trees that had already been felled, and laid down a uniform charcoal measure. The mining regulations for Carniola and Gorizia of 1575 largely follow the mining regulations of 1553 but also contain some new provisions. This likely indicates the increased deforestation in the course of the 16th century, especially in the decades before the regulations were issued. More numerous and detailed instructions on forest management are provided in forest regulations. In neighbouring areas, forest regulations concerning metallurgical activities were issued for Styria (1539) and Canal Valley and Bleiberg area (1584).

Estimates of annual charcoal consumption and the required deforestation in Carniola and Gorizia, as well as the Jesenice ironmaking area, generally rely on data from sources but involve multiple variables. Because of these variables, the estimate of the cleared forest area in particular needs to be approached with considerable caution and critical distance. Nevertheless, the results for the Jesenice area suggest that noticeable deforestation likely occurred as early as in the second half of the 16th century.

[105] CLEERE, H., *The Iron Industry*, p. 122; PLEINER, R., *Iron in Archaeology*, p. 127.

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SAŽETAK

Članak se bavi korištenjem i upravljanjem prirodnim resursima, posebno šumama, za potrebe proizvodnje željeza na slovenskim područjima. Sve do 19. stoljeća, drveni ugljen bio je glavno gorivo koje se koristilo za vađenje i preradu željeza. Razvojem intenzivne proizvodnje željeza počela je rasti i potrošnja ugljena, ali do 16. stoljeća nije predstavljala značajnu prijetnju opstanku šuma. Vlasnici željezara morali su dobiti dopuštenje od vlastelinstava za korištenje šuma, a zauzvrat su plaćali dažbine koje su se razlikovale među vlastelinstvima. Od kasnog 15. stoljeća, sporovi vezani uz sječu za proizvodnju drvenog ugljena postali su učestaliji, uključujući sukobe među željezarskim radnicima iz različitih vlastelinstava i između željezarskih radnika i vlastelinstva. Potonji su rezultat provođenja zemaljsko-kneževski rudarskog regala i vlasništva nad šumama u rudarskim područjima. Zemaljski knez je učvrstio ovo vlasništvo izdavanjem rudarskih propisa 1517., 1553. i 1575. godine, koji su također pružali upute za upravljanje šumama. Svaki sljedeći rudarski propis sadržavao je detaljnije odredbe o krčenju šuma, što ukazuje na sve veći broj područja iskrčenih za potrebe proizvodnje željeza. Posljednji dio rada pokušava procijeniti godišnju potrošnju drvenog ugljena i stopu krčenja šuma za potrebe proizvodnje željeza u Kranjskoj i Goriškoj, kao i u željezarskom području Jesenica, krajem 16. stoljeća. Zbog oskudnosti sačuvanih izvora koji dokumentiraju potrošnju drvenog ugljena, i posljedično korištenja brojnih više ili manje pouzdanih varijabli u izračunu, dobiveni rezultati trebaju se promatrati s velikom dozom kritičke distance. Ipak, procjene sugeriraju da je čak i tijekom tog razdoblja bilo potrebno iskrčiti relativno velike površine šuma za vađenje i preradu željeza.

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