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The Agricultural Geography of the Nasu-Fan District, Tochigi Prefecture (9) —Irrigation System of Paddy Field[1]—

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In this paper,[4] the agricultural regions of the Nasu-fan district (Fig. 1), already established on the basis of staple crops including paddy rice, are compared and contrasted, from the viewpoint of irrigation system. The principal sources of irrigation water of these subsections are summarized as follows. They are arranged, in order as far as possible, according to the characteristics of the respective region, not necessarily according to its importance.

The upland field section....

α_1: The Old-Kinomata canal

α_2: The 1st and the 2nd branches of the Nasu canal, pumps, residual water from α_1 and α_3

α_3: The Hikinuma-bori canal

β: The 3rd and the 4th branches of the Nasu canal, pumps

The paddy field section....

a: Springs, pumps, residual water from α_2 and β

A: Springs, permeating water from valley walls, canals from the Hôki-gawa, pumps, residual water from a and β

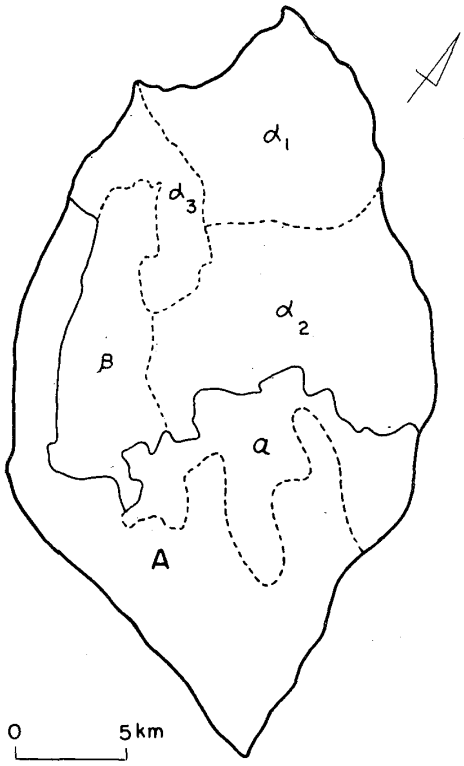

Fig. 1. The agricultural regions of the Nasu-fan

The district under discussion is a spindle-shaped confluent fan, de-

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4) Matsui, Isamu: The Agricultural Geography of the Nasu-Fan District (6), The Three Unit Regions Analyzed from the Viewpoint of Areal Differentiation Regarding Staple Crops (Jap.). Bull. Geogr. Inst., Tôkyô Univ. 3 (1954), pp. 178–201.

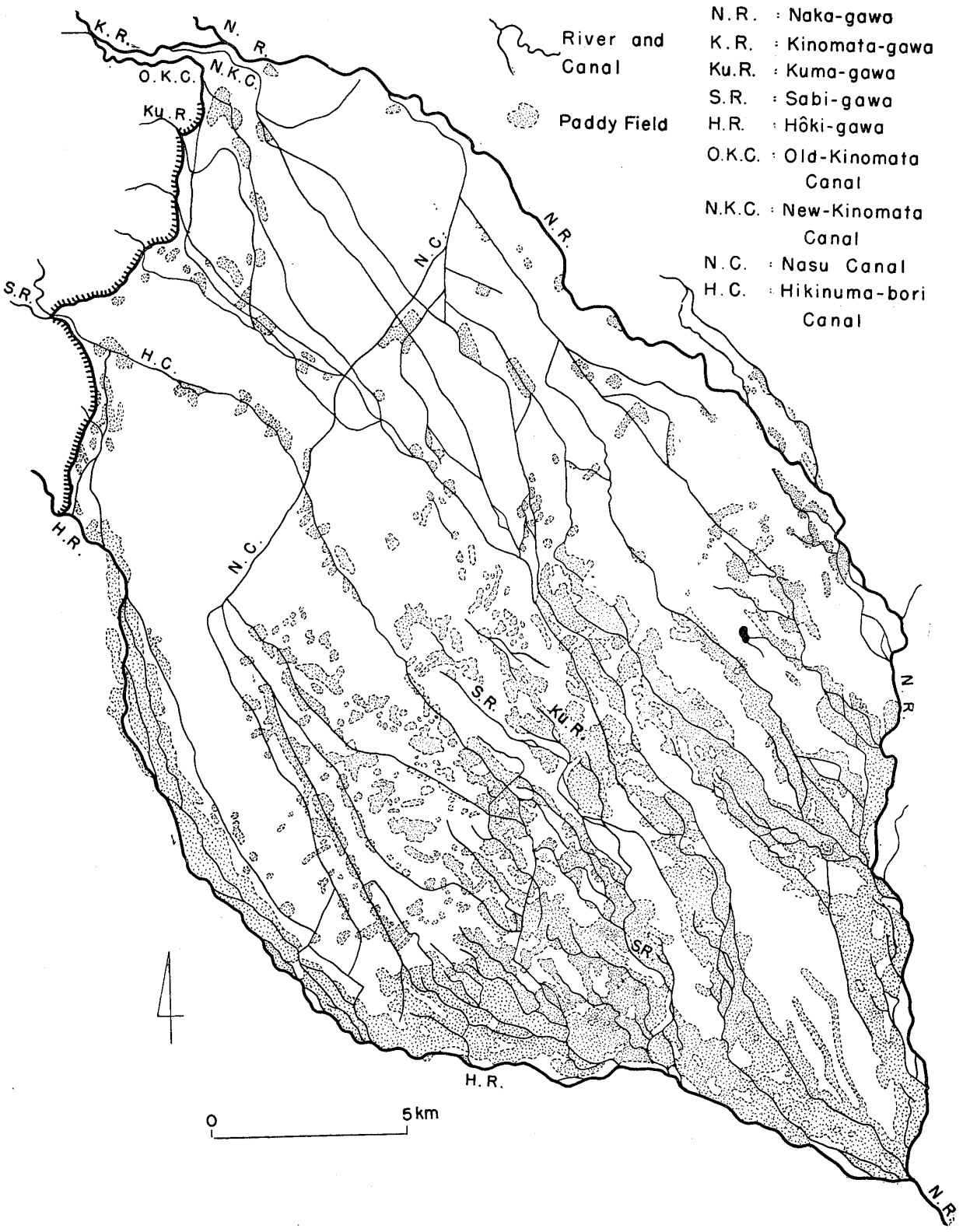

Fig. 2. The irrigation system of the Nasu-fan

posited by the rivers: the Naka-, the Kuma-, the Sabi- and the Hôki-gawa (Fig. 2), and afterwards dissected by uplifting. The altitude ranges from 130 to 600 m. The Naka-gawa which runs down along the northern and the eastern side of the fan, and the Hôki-gawa bordering the western and the southern side, are engraving the fan surface by 60–20 and 30–10 m respectively. The Sabi-gawa which flows through the fan surface, in the direction of the longitudinal axis of the fan, is eroding the surface both in the head area higher than 380 m in altitude, and also in the terminal area lower than 240 m, while it continues to deposit in the central area between them. Here the river-water disapears, sinking into the ground in the ordinary time; nevertheless when the river rises, it floods frequently over the neighbouring surface of the fan. The Kuma-gawa is far smaller than the Sabi-gawa, although it runs also through this fan.

(1) The Upland Field Section

This section occupies the head and the central area of the fan, and ranges from the uppermost part in the former, 600 m in altitude, to the place about 200 m in the western and 240 m in the eastern half of the latter. According to the agricultural census in 1947, the percentage of the paddy field to the total cultivated area, i.e. the degree of paddy field, is only about 10 per cent in α_1 and α_2, while it is some 30 per cent in α_3 and 20 per cent in β (Table 1). These subsections have respectively its own characteristic in irrigation system.

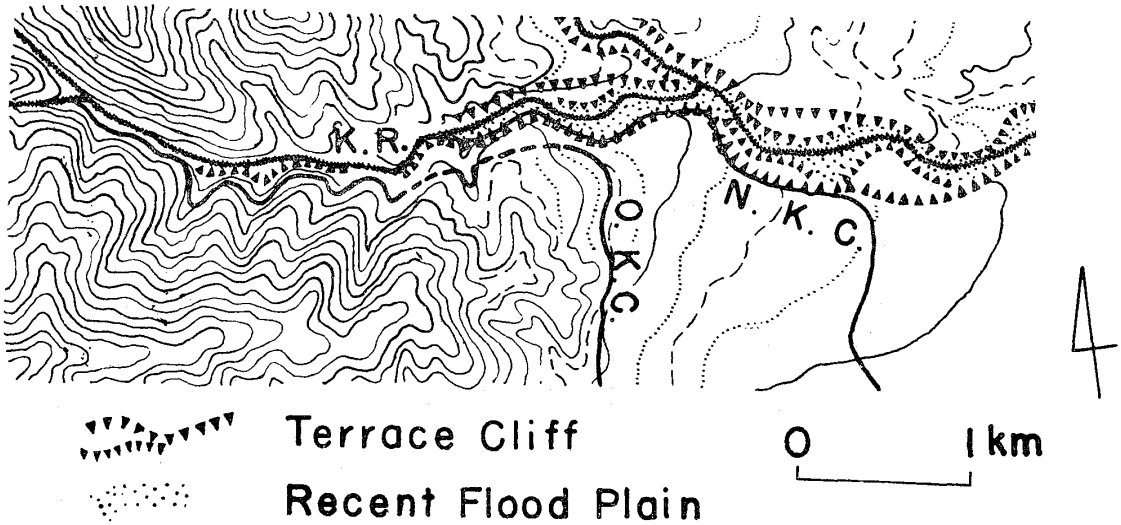

Fig. 3. The physiography in the neighbourhood of the inlet of the Old-Kinomata canal

Table 1. The degree of paddy field (%) in the agricultural regions

Upland Field Section α			Upland Field Section β	Paddy Field Section	
α_1	α_2	α_3		a	A
7	10	28	20	42	68

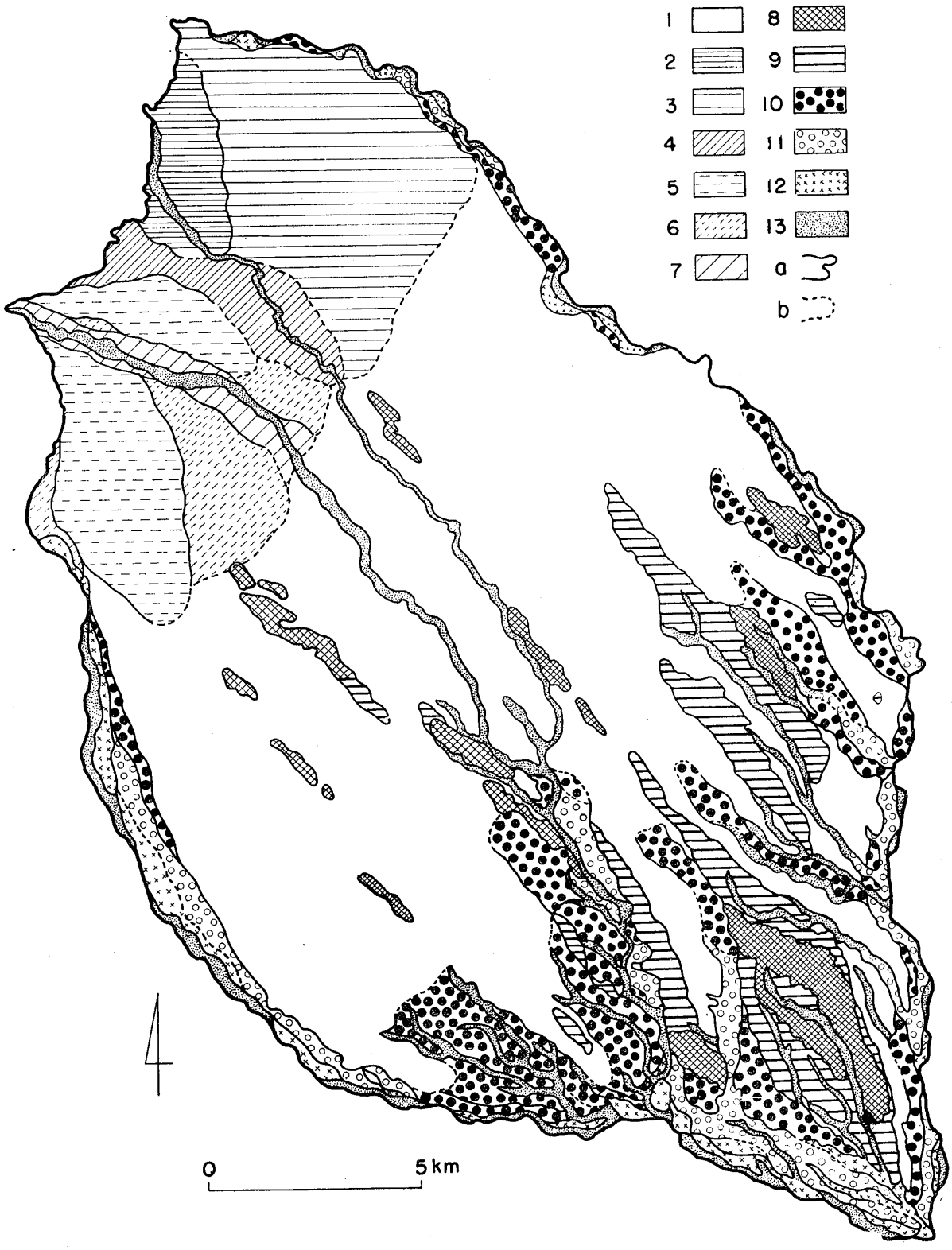

Fig. 4. Geomorphologic map of the Nasu-fan

The division of the surfaces of the Nasu-fan from the geomorphological point of view

(1) Nasuno-surface
Most extensively and continuously distributed, nearly flat plain, considered as the initial surface of the Nasu-fan

(2) Momura-surface
An old fan deposited by the Kuma-gawa, more or less dissected

(3) Anazawa-surface
An old fan formed by the Naka-gawa, steeper than the Nasuno-surface adjoining south

(4) Takabayashi-surface
Deposited by the Kuma-gawa and other rivulets on the lower portion between the Anazawa- and the Yugû-surface

(5) Yugû-surface
An old fan formed by the Sabi-gawa, being the 1st terrace of this river

(6) Orido-surface
Deposited by the Sabi-gawa after the Yugû-surface was uplifted, being the 2nd terrace of this river

(7) Yokobayashi-surface
Deposited by the Sabi-gawa after the Orido-surface was uplifted, being the 3rd terrace of this river

(8) Gon-gen-yama-surface
Maturely dissected hills remaining uncovered by the Nasuno-surface, 20–50 m higher than the neighbouring Nasuno-surface

(9) Kanemaruhara-surface
Old dissected fan remaining uncovered by the Nasuno-surface, 5–10 m higher than the neighbouring Nasuno-surface, forming more or less flat uplands

(10) Chikasono-surface, including upper terrace along the Naka- and the Hôki-gawa
Valley flats, now uplifted highest among a series of valley floors formed by engraving the Nasuno-surface, and adjoining the latter surface generally with cliffs of 2–4 m; the northern margin, however, transitting gradually into the latter; being the upper terrace along the Naka- and the Hôki-gawa

(11) Hiruta-surface, including middle terrace along the Naka- and the Hôki-gawa
Valley flats 2–3 m lower than the Chikasono-surface, in places directly adjoining the Nasuno-surface with 6–7 m cliffs; being the middle terrace along the Naka- and the Hôki-gawa, 5–10 m high from the river floor

(12) Kotanejima-surface
Being distributed in fragments in the lower area of the Hôki-gawa, 4–5 m higher than the present river floor
Sarado-surface, including lower terrace along the Naka- and the Hôki-gawa 2–3 m higher than the present river floor

(13) Recent flood plain

a: Boundary line between surfaces
b: Boundary line between surfaces transitting with topographic conformity

The subsection α_1 which occupies the northernmost part of the fan is the area mainly irrigated by the Old-Kinomata canal (Figs. 2 and 3). At the point of 630 m in altitude, the canal is distributed from the Kinomata-gawa, a tributary of the Naka-gawa, and after running down 4 km, partly as underdrain, sometimes along the steep walls of the gorge, and sometimes on the river terrace, it reaches the fan surface (Anazawa-surface, See Fig. 4) at the point of 590 m in altitude, where it becomes 70 m higher than the neighbouring river floor of the Kinomata-gawa. Shortly after this, the canal parts into two streams. The one flows southwards upon the Kumagawa fan (Momura-surface) along the foot of the western neighbouring mountain, the other runs southwards along the contiguous zone between this fan and the Naka-gawa fan (Anazawa-surface) or a little east of this zone. And both irrigate a small space of the paddy field distributed in the western half of α_1. The residual water of these two branches is united into a runnel after entering α_2.

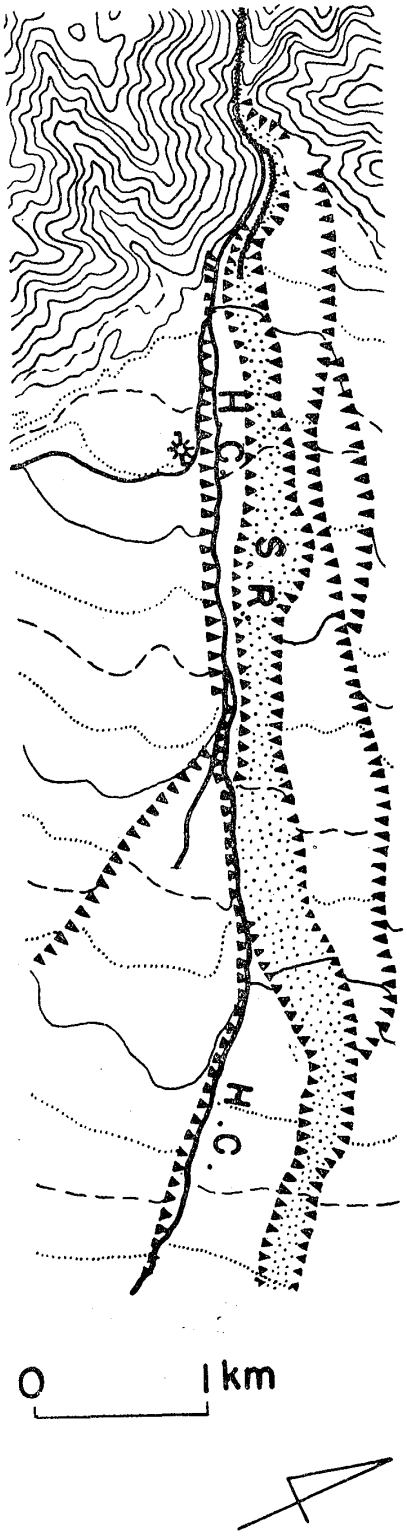

Fig. 5. The physiography in the neighbourhood of the inlet of the Hikinuma-bori canal

The New-Kinomata canal (Figs. 2 and 3), which branches off from the Kinomata-gawa in the place of 540 m in altitude, enters the above mentioned Anazawa-surface at the point of 530 m. It is scarcely used, however, for irrigation of paddy fields in α_1.

The subsection α_3 is, as a whole, an irrigation-area of the Hikinuma-bori canal (Figs. 2 and 5), although the western and the eastern halves of the section are somewhat different each other. In the former, paddy fields are cultivated a little on the Yugû-surface, intermittenly along the mountain foot, utilizing a branch of the Hikinuma-bori canal and other rivulets running down from the mountain region and entering into the branch.

On the other hand, the irrigation water of the eastern half area of α_3 is supplied ex-

clusively by the Hikinuma-bori canal, which branches off from the Sabi-gawa. In the head area, the Sabi-gawa accompanies terraces of three steps intermittently along both sides, of which the height from the river-floor is about 30, 10–15 and 2–3 m respectively.

The Hikinuma-bori canal parts from the Sabi-gawa near the point of 500 m in altitude, shortly before the river reaches the fan. Here the canal is constructed mainly along the valley wall, and partly as under-drains. Soon after flowing out on the fan, it ramifies in the upper and the lower stream, while it runs down along the cliff of the 1st terrace (Yugû-surface). Although the former is utilized partly for a small hydroelectric plant, the residual water of which is drawn shortly upon the Yugû-surface. It is the above-mentioned branch that irrigates the western half of the subsection. The lower branch, i.e. the main stream of the Hikinuma-bori canal, soon appears upon the 3rd terrace (Yoko-bayashi-surface) being narrow; in places where this terrace is lacking, it runs down again along the cliff of the 1st terrace. It branches off onto the 2nd terrace surface (Orido-surface), in the neighbourhood where this surface is beginning, and irrigates a small area of paddy fields upon it.

The main stream itself, after running down along the cliff of the 2nd terrace, is drawn onto the 3rd terrace surface, which appears again and develops its width in a short distance, and supplies water to the paddy fields cultivated upon it. It then appears on the Nasuno-surface —here the Sabi-gawa constitutes the present alluvial plain—near the point of about 370 m in altitude, as the terrace gradually transits into the surface without any topographic unconformity. In this way, in the eastern half of α_3, a small space of the paddy field forming patches is distributed on these upper, middle, and lower terraces, and further on the present fan surface.

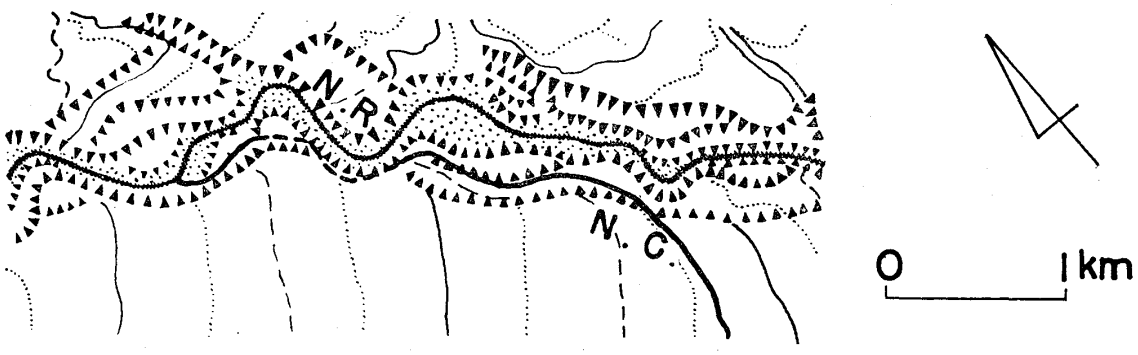

Fig. 6. The physiography in the neighbourhood of the inlet of the Nasu canal

Next, β is an area irrigated predominantly by the 3rd and the 4th branches of the Nasu canal (Figs. 2 and 6). It branches off from the Naka-gawa near the point of 420 m in altitude, and appears on the lower terrace surface which is 3–4 m higher than the river floor. After running

through a tunnel 1 km long, under the middle terrace surface, which is 35 m higher than the river floor, and also under the fan surface, it comes out onto the surface of the terrace concerned and the upper one, and flows down about 2 km. Then it appears on the southern marginal part of the Anazawa-surface, near the point of 410 m in altitude, where the latter terrace transits into this surface with topographic conformity. Shortly the 1st and the 2nd tributaries branch off from it toward SE; while the main canal, running through the southern part of α_1, then crossing α_3, reaches the northern part of β, thus traverses the fan from NE to SW, about 13 km far in distance. On its way it crosses under the river floors of the Kuma- and the Sabi-gawa, usually both having no surface water.

In β, from the canal the 3rd branch diverges at the point of 320 m in altitude and leads toward SE. The remaining water, forming the 4th branch, parts into three branches again. They all run down following the direction of the longitudinal axis of this subsection, namely from NW to SE, in a similar way as the 3rd branch does. Besides these canals, the ground water lifted by pumps (Fig. 7) is used for irrigation. Thus the paddy fields on the Nasuno-surface are more or less continuously distributed from 300 to 210 m in altitude.

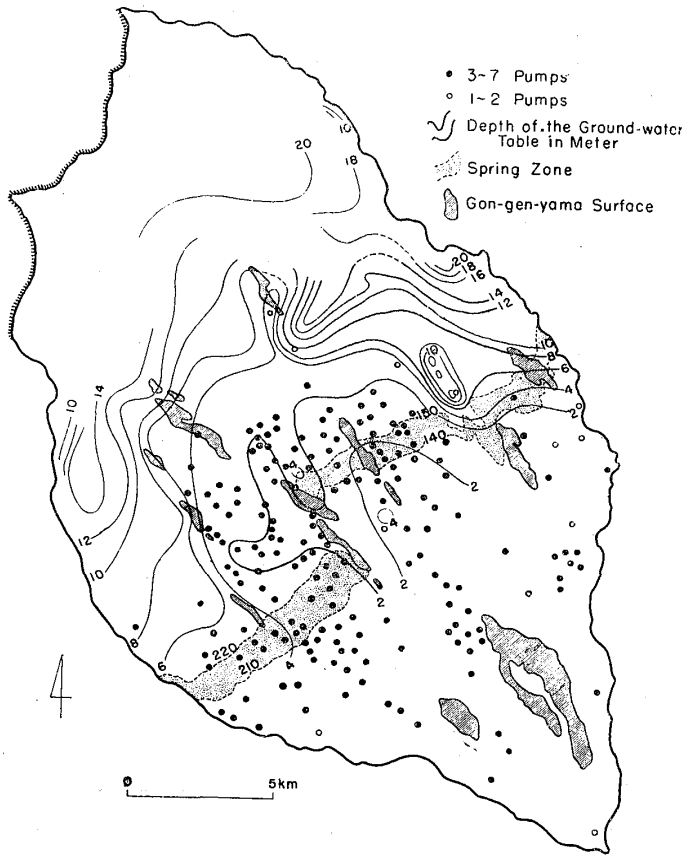

Fig. 7. The distribution of the water-lifting pumps in the Nasu-fan in 1949

Finally, α_2 is irrigated by the residual water of the Old- and the New-Kinomata canal and the Hikinuma-bori, in addition to the 1st and the 2nd branches of the Nasu canal. Moreover, in the southern half of this subsection, pumps have increased, in number, rapidly in these recent years. With supply of water from these sources, a small area of the paddy field, forming patches, is cultivated mainly on the Nasuno-surface.

The northern limit of the pumps (Fig. 7) in 1949 extends from α_2 to β, where ground-water table exists at the depth of about 4–5 m with

some exceptions[5]. The altitude of this limit is ranging from 250 m in the eastern part of α_2 to 270–280 m in the central part of α_2 and also in β. The ground-water table increases rapidly its depth from here northwards (Fig. 7). In this way, except the eastern half of α_2, the utilization of ground water for irrigation is now practised even in areas, lying 2–7 km far to the north of the spring zones (Figs. 7 and 8), which will be mentioned later on.

(2) The Paddy Field Section

Regarding the fan as a whole, the upper limit of the spring (Fig, 8) is quite different in altitude, between the eastern and the western parts of the hill (Gon-gen-yama-surface), which is located to the east of the Ôtawara town, and stretches along in the direction of the axis of the fan. In the eastern half, the upper limit is situated in the narrow zone between 240–250 m in altitude; while in the western half between 210–220 m with a few exceptions, and generally it increases its altitude towards the hill. In the paddy field section lying to the south of the spring zone, springs are gushing out and form valley head on the Nasuno- and the Chikasono-surface. The density of springs, however, is quite different in the eastern and the western halves of the fan, as will be shown later.

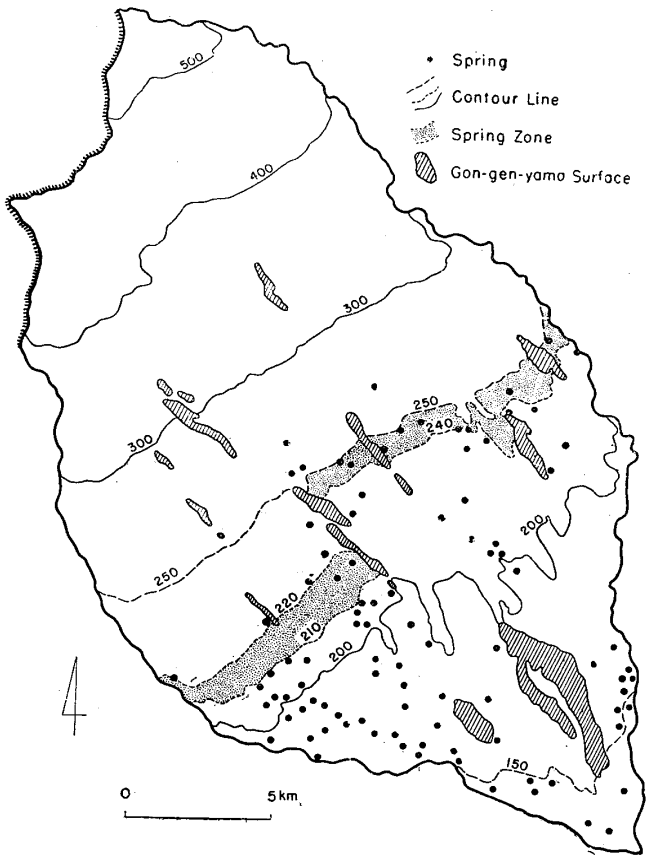

Fig. 8. The distribution of the springs in the Nasu-fan

As for the degree of paddy field, the paddy field section, being classified into the main part A and the peripheral part a, is far higher than the upland field section (Table 1). In opposition to the latter, the paddy field section is characterized by far extensive paddy fields, which

5) The data concerning the ground water table are taken from "The Record of the Survey on the Existing Wells" (Oct. 1, 1950), in "The Series of Reports of the Investigation on Land Reforming of the Nasuno-ga-hara" (Jap.) by the Ministry of Agriculture and Forestry. Figure 7 is based upon these data.

6) Matsui: op. cit., pp. 180 and 197.

utilize springs as the new water source. Besides, reflecting the above-mentioned narrow belt of the spring zone, the transition[6] of the degree of paddy field between these sections appears clearly as discontinuous, i.e. ranging from 25 to 46 per cent.

According to Prof. Takeuchi[7], the ratio of water catchment area of those rivers which have ever deposited and are still depositing the Nasu-fan to the area of the fan itself is extremely small, when compared with those ratios obtained in most of the fans in our country. Therefore, it is only a small area of the paddy field that can be cultivated in the upland field section north of the spring zone, even if water is supplied from the rivers through the existing canals, since they are liable to leak considerably. On the other hand, the rain water falling upon the relatively extensive area of this section, the underground flows of the Sabi- and the Kuma-gawa, and last but not least, the water leaking out from the canals—these are the principal sources which maintain the large quantity of underground water in this section. Consequently the paddy field section to the south of the spring zone is supplied with abundant surface water, favoured by a number of springs, and in addition, by permeating water from cliffs among the Nasuno- and the lower surfaces.

The Chikasono- and the Hiruta-surface forming the shallow and flat valley floors, 1 km wide at the most, develop in the terminal area of the fan. The former penetrates up to the place of about 270 m in altitude, and extends even to a part of α_2. On the other hand, the latter is limited mainly in A. The permeating water—ground water, temporary permeating rain water or leaking water from paddy fields upon the upper surface—from the lower part of valley walls or terrace cliffs, which lie among the Nasuno- and the lower surfaces, forms valley head if its quantity is abundant. Even though its quantity is scanty in a place, it joins with the running water on the valley floor and the latter gradually increases its volume. In this respect, it is perhaps an important water source in A. No permeating water is found, however, from cliffs, between the Nasuno- and the upper surfaces.

In the peripheral subsection α paddy fields distribute rather continuously, especially upon the Nasuno- and the Chikasono-surface, of which the water sources are the springs, the ground water being lifted by pumps, as well as the residual water from α_2 and β.

The subsection A, which is the principal part of the paddy field section, occupies the terminal, as well as the marginal, area of the fan along the Hôki- and the Naka-gawa. The surface configuration of this subsection differs between the eastern and the western part of the Sabi-gawa. In the western half, where the Nasuno- and the Chikasono-surface

7) Takeuchi, Jôgyô: The Controlling Factors Concerning the Irrigation for Paddy Field Cultivated upon the Fan (Jap.). Sci. Res. Rep., Dept. Educ., Waseda Univ., 2 (1953), pp. 143–157.

stretch extensively, the Hiruta-surface is restricted exclusively to narrow valley floors which engraves the latter. In the eastern half, however, these three surfaces develop altogether. Here, moreover, a group of remnant surfaces of the old fan (Kanemaruhara-surface) and also hills (Gon-gen-yama-surface), both remained uncovered by the deposition of the recent fan (Nasuno-surface), surpass the Nasuno-surface and elongate in the direction of the longitudinal axis of the fan. In the western half, such topographic features are rarely found.

The characteristics of the irrigation system are more or less different between these two halves. In the eastern half, only a small number of springs scatter upon the Nasuno- and the Chikasono-surface. The lifting pumps, also existing mainly on these surfaces, are much fewer than those in *a*. Using these water sources, as well as using the residual water which flows down from *a*, and permeating water from valley cliffs, paddy fields are cultivated upon the Nasuno- and the flat valley floors of the Chikasono- and the Hiruta-surface. They form three distributing belts, ranging along the longitudinal axis of the fan, between the remnants of the old fan and the groups of the hills. The hills and the old fan surfaces are principally covered with woods, on the contrary.

In the western half, the residual water from the upper subsections and a few pumps are used as in the eastern half. A number of springs and permeating water from valley walls are, however, concentrating most densely throughout the fan, especially upon the western part of the Chikasono-surface, on which paddy fields are continuously cultivated. On the other hand, upon the Nasuno- and the eastern part of the Chikasono-surface, where the density of springs is rather small, paddy fields are distributed, sometimes interrupted by upland fields and also by some wood-lands.

Along the Hôki-gawa a series of terraces are developing; their characteristics being, however, more or less different between the western and the southern margin of the fan. In the former terrace, cliffs are frequently indistinct; on the other hand, in the latter 4 steps are clearly indicated. Though the development of terraces are relatively restricted along the Naka-gawa, it is possible to recognize three steps (excluding the terrace-formed Nasuno- and the Kanemaruhara-surface) rather distinctly, along the eastern margin of *A*. The 1st and the 2nd terrace surfaces of both rivers continue to the valley floors (Chikasono- and the Hiruta-surface respectively) in the fan. The surfaces corresponding to the 3rd and the 4th terraces do not exist in the interior of the fan.

In *A*, paddy fields on the 1st and the 2nd terraces of the Hôki-gawa, which bound the fan on the south, and also paddy fields on those terraces of the Naka-gawa are supplied with water by the irrigation canals, which flow out onto the terraces from the valley floors mentioned above

and from the Nasuno-surface as well. The permeating water from the terrace walls is also used for irrigation. On the lower terrace (Sarado-surface) along the Hôki- and the Naka-gawa, paddy fields are irrigated by canals from these rivers.

As to the part of the Hôki-gawa, bordering the fan on the west, the altitude difference between the river floor and the Nasuno-surface is about 10 m, with some fluctuations at some parts. The mode of transition from the Nasuno-surface to the river floor is various, in one place, the transition is made with 2 or 3 steps of terraces with cliffs of 1–2 or at most 4–5 m high, in other places, the transition is rather gradual, without any steep cliffs. On these terraces and on the slow slopes, paddy fields develop continuously, making jointly a zone of the width of about 1 km. Regarding its irrigation system, a marked difference is noted from that of the before-mentioned terraces along the southern borderland of the fan. As no water flows down from the interior part of the fan, and also no water permeates from the terrace cliffs with only one existing exception, the paddy fields are maintained exclusively by canals from the Hôki-gawa. There are at least 12 branching points along the left bank alone of the river. One of the canals is dammed up on the Nasuno-surface.

Thus, viewed from the point of the irrigation system, *A* is sub-divided into 2 areas, i.e. the narrow zone along the Hôki-gawa, bordering the western part of the fan, and the remaining area as a whole. In the former the Hôki-gawa in particular, and in the latter the other surface water and the ground water of the fan itself, are used as the main source of irrigation water.

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