Agriculture in Hokkaido

Hokkaido University

Sappro, Japan

Agriculture in Hokkaido (Second edition 2009, v2)

Printed by
Laboratory of Crops Science, Research Faculty of Agriculture, Hokkaido University
N9 W9 Kita-Ku, Sapporo 060-8589, Japan

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PREFACE

Agriculture in Hokkaido dawned in 1868; the time when the Meiji Government was established. Warriors who were deprived of their positions by the new government after the Meiji Revolution, and farmers who could afford only small area in the main islands of Japan, immigrated to Hokkaido. They cleared the land and planted crops facing sever winters of Hokkaido. Presently, Hokkaido leads agriculture in Japan, proudly tops the production of rice, wheat, potato, beans, sugar beet, vegetables, and especially dairy products.

The people of Hokkaido, however, shall never forget that it is the hard work of their predecessors for more than hundred years that has earned the present position for Hokkaido. At the same time, misunderstanding between immigrants and native Ainu people, and environmental degradation caused by reclamation of Hokkaido, should be matters of concern.

This book describes past, present and future of Hokkaido's agriculture. The articles for this have been contributed by the professors outstanding in their respective fields in Hokkaido University. All chapters have been written in a simple language and illustrated with relevant photographs. Though this book has been produced as a textbook for the foreign students at Hokkaido University, it can serve a wide range of readers. It will be a great pleasure for us if this book is read by all concerned including visitors to this lovely land of Hokkaido.

Representing the contributors, Kazuto Iwama
March 2009

Characteristics of Ecological System

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Chapter 1

Characteristics of Ecological System

Masashi Ohara

The island of Hokkaido is the northernmost in the Japanese archipelago. It faces the Sea of Okhotsk and is separated from Honshu by the Tsugaru Strait and from Sakhalin by the Soya Strait. The lowlands of Hokkaido represent a transitional zone between cool temperate forests in the south and sub-arctic forests in the north. The mostly upland eco-region of Hokkaido is situated in the cold-temperate and sub-arctic/sub-alpine climate zones. This chapter introduces the importance and uniqueness of wildlife and ecosystem of Hokkaido.

1. What is Hokkaido Island?

(1) Where and how big is this?

The map (Fig. 1-1) shows that Hokkaido is located between 41°21'N and 45°33'N latitude, and 139°20'E and 148°53'E longitude. It is in the same latitude as Portland, Oregon (USA), Toronto (Canada) and Rome (Italy). The area of Hokkaido is 83,451 km^2, which is 22% of the total land area of Japan. The population of Hokkaido is 5.69 million (cf. 11.77 million in Tokyo) and 32% (1.856 million) of people live in Sapporo city, which is the capital of Hokkaido. The population density of Hokkaido is roughly 68 people/km^2 compared to 5384 people/km^2 of Tokyo.

(2) Geography

Hokkaido is a biogeographically important region. The central Hokkaido has mainly mountains and highlands. It includes the Taisetsu mountain range (Fig. 1-2), which has the highest summit Mt. Asahidake (2291 m ASL), the Tokachi mountains and east Taisetsu mountains. The Taisetsu mountain range is also called the "The Roof of Hokkaido". In the north of the central highlands is the Kitami mountain range. Towards the Sea of Japan runs the Teshio mountain range from north to south. In the south of the central highlands stretch the sharp

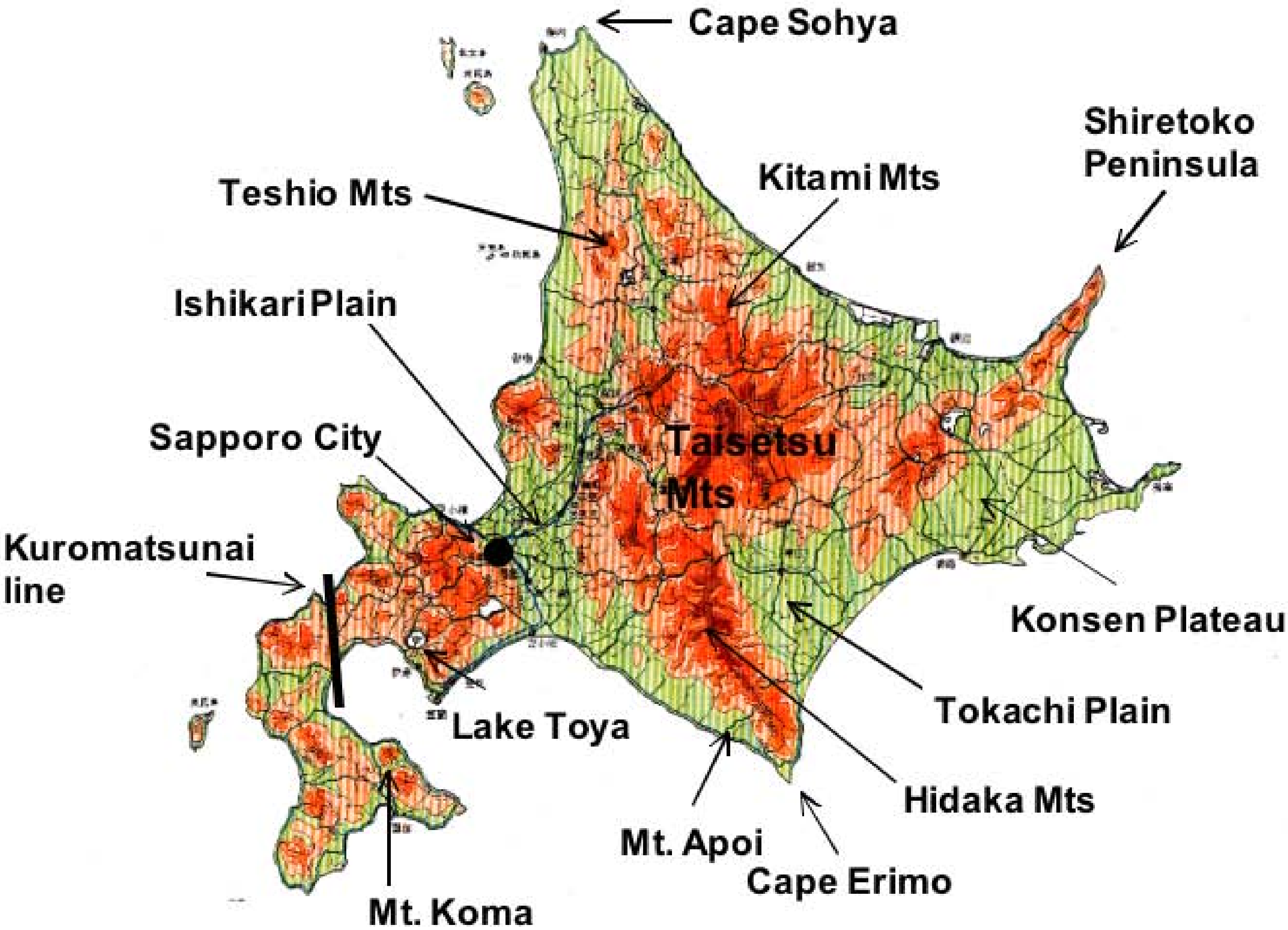

Fig. 1-1. Geographical map of Hokkaido

ridges of the Hidaka mountain range,140 km toward cape Erimo. The Yubari mountain range lies parallel to the west of the Hidaka mountain range. These spinal mountains that run from cape Sohya to cape Erimo, are truly the backbone of Hokkaido, and undoubtedly influence the climate and vegetation of Hokkaido.

In eastern Hokkaido, is Shiretoko peninsula, which has been designated as a world heritage site. The Akan volcanoes are in the southernmost part of the Chishima volcanic zone. In the southwest area of the Ishikari lowland zone, there is a chain of active volcanoes such as Mts. Tarumae, Usu, Koma (Fig. 1-3), Yohtei and the Niseko ranges. Because of volcanic activities in Hokkaido, there are many crater lakes, namely Shikotsu, Toya (Fig. 1-3), Kussharo, Akan and Mashuu.

(3) Climate

Hokkaido has four distinct seasons like the rest of Japan. As it lies in far north, it generally has cooler summers, and cold, snowy and blustery winters (Fig. 1-4). The average temperature in August is around 22°C (72°F), while in January it ranges from -12°C to -4°C (10°F to 25°F) depending on elevation and latitude. Unlike the other major islands of Japan, Hokkaido is normally not affected by "Tsuyu" and typhoons in the rainy season. During winter, passage through the Sea of Okhotsk is often disturbed by large ice floes broken loose from the Kamchatka peninsula. Due to high winds that occur during winter, air travel and maritime activity almost come to a halt in the northern coast of Hokkaido.

2. Vegetation

Since the geographical structure of Hokkaido is complex with mosaic distributions of volcanic, sedimentary and metamorphic rocks, this island has been historically providing a variety of habitats for wildlife. It has interesting Japanese Islands, Sakhalin and Kurile, and its flora and fauna are a mixture of species from southeastern Asia, Siberia and North America. The southern sea barrier, Tsugaru Strait, is the bio-geographical boundary, "Blakiston Line", which has interrupted the migration of many animals between Hokkaido and Honshu,

Fig. 1-2. A view of Taisetsu Mountains (Photo by Dr. Akira S. Hirao)

the main island of Japan. On the other hand, in the northern barrier, Sohya Strait, a land bridge was frequently formed in the glacial epoch. Hokkaido is located in a zone of high snowfall and this has facilitated a mixture of summer-green deciduous trees and evergreen coniferous trees. Actually, the mixed forest of this island is considered to be the richest in species among all temperate and boreal vegetations of the world.

(1) Boreal coniferous forests

This forest cover is dominated by Asian spruce (*Picea jezoensis*) and Sachalin fir (*Abies sachalinensis*). These are distributed at high altitudes of Taisetsu and Hidaka mountain ranges as well as at comparatively lower elevations of Sohya, Kushiro and Nemuro districts. Dominance of *Picea jezoensis* increases at higher altitudes with increasing levels of stability.

Conifer forests are found up to an elevation of approximately 1,500 m in Hokkaido; above this point alpine conditions predominate. Stone pine (*Pinus pumila*) forms low (1-2 m) and dense growth in alpine areas, with poorly developed undergrowth, but vigorous mosses on the ground. The abrupt change of the landscape from high forests to low lying *Pinus pumila* shrubs is impressive and can be easily recognized. In the alpine zone, the coniferous species are sometimes accompanied by deciduous broad-leaved shrub communities. The main associations found are of birch-alder (*Betula ermanii-Alnus maximowiczii*) and mountain ash (*Sorbus sambucifolia*). Alpine heaths composed conspicuously of *Empetrum nigrum* and dwarf shrubs (*Arcterica nana-Loiseleuria procumbens* association) are found at some of the highest altitudes (Kudo 1993).

The sub-alpine coniferous forests that used to extend up to the northeastern hills and plains in coastal areas, for the most part, have been cut down. However, compared to the rest of the country there still remain relatively intact large tracts of forests in Hokkaido. Mt. Daisetsu National Park is the largest national park in Japan covering several volcanic mountains with extensive spruce and fir forests on its slopes.

(2) Deciduous forests

Fig. 1-3. A volcanic mountain, Mt. Koma (top) and a crater lake, Lake Toya (bottom)

The lowlands of Hokkaido represent a transitional zone between cool temperate forests in the south and sub-arctic forests in the north with the exception of the Oshima peninsula. This eco-region covers low hills and plains of Hokkaido. The lowland deciduous forests of the island are dominated by oaks (*Quercus* – especially Mongolian oak *Quercus mongolica* var. *crispula*), basswoods (*Tilia japonica*), elm (*Ulmus davidiana*) and ash (*Fraxinus mandshurica*), typically with undergrowth of dwarf bamboo (*Sasa* species). The base of the peninsula forms a boundary known as the Kuromatsunai line (Tatewaki 1958; cf. Fig. 1-1). The beech (*Fagus crenata*) forest, representative forest type in the cool-temperate zone of Japan, is the only forest present throughout the Oshima peninsula, which is situated south of Kuromatsunai lowland. This is a striking northern limit for the distribution of this species.

The campus of the Hokkaido University is located in the center of Sapporo city developed on the drainage basin of two big rivers, Ishikari and Toyohira, in Ishikari plain. In the campus, there are many large elm (*Ulmus davidiana*), maple (*Acer mono*) and ash (*Fraxinus mandshurica*) trees, which prefer mesic and rich soil (Fig. 1-5).

In spring as days become longer and temperature rises, brown deciduous forests and fields of Hokkaido, start to turn green. The forest floor in particular, brightens as scores of wild flowers, “the spring ephemerals”, bloom in April and May. These flowers open, and leaves unfurl for a few days only. During this short period, the spring ephemerals show many unique and different ecological features (cf. Fig. 1-5). Although most of the species of Araceae are common in tropical regions, *Lysichiton camtschatcense* (Fig. 1-5a) of this family is adapted to cool temperate regions, having unique life forms. *Erythronium japonicum* is one of the representative spring woodland perennials of Japan (Fig. 1-6b). The large showy pinkish flowers of this species have been attracting many flower lovers. *Corydalis fumariifolia* (Fig. 1-6c) has deep blue palate, arranged in racemose inflorescence of 1 to 15 flowers. Each flower has a spur in which nectar collects. Nectar attracts bumblebees, which is an important pollinator. A representative wild flower of Hokkaido worth mentioning is *Trillium camschatcense* (Fig. 1-6d). This flower can be seen on the main campus and in the Botanical garden of Hokkaido University. This flower figures in the emblem of

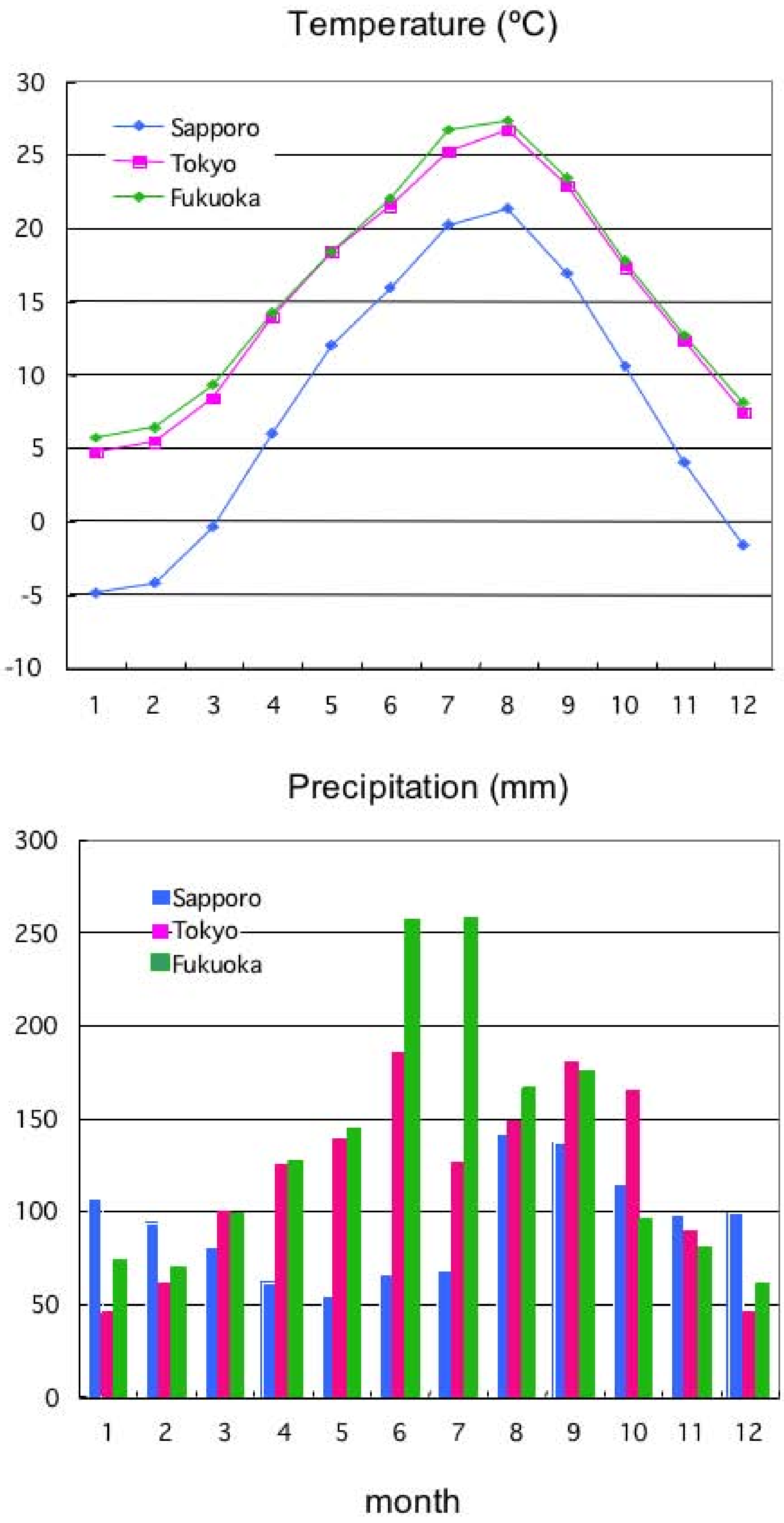

Fig. 1-4. Average temperature and precipitation of Sapporo, Tokyo and Fukuoka

Hokkaido University. In May, one finds *Trillium camschatcense* in bloom everywhere in Hokkaido (Fig. 1-5). In late spring (early June), lily-of-the-valley, *Convallaria keiskei* with aromatic white flowers starts to flower (Fig. 1-6e). In summer (during July) in deciduous forests, one finds tall plants (1.5–2.0 m high) of *Cardiocrinum cordatum* (Fig. 1-6f) with large conspicuous flowers.

(3) Mixed conifer-hardwood forests

The conifer-hardwood forest is a mixture of boreal evergreen conifers and temperate deciduous hardwoods that differ in life forms but grow in the same place (Fig. 1-7). However, in some cases, the mosaic-like areas of pure stands of different species growing adjacent to one another are also called mixed forests. The mixed forests can be seen not only in the Far East including Hokkaido, but also in southern Scandinavia and northern parts of Eastern Europe, and those between the Great Lakes regions and the northernmost of the Appalachian mountains of North America. Tatewaki (1958) named this type of forest zone the “pan-mixed forest zone”, which is more commonly known as the “hemi-boreal zone” (Hamet-Ahti et al. 1974) or the “boreo-nemoral forest ecotone” emphasizing the transitional aspects (Uemura 1993).

3. Biodiversity Features

(1) Flora

There are 2,250 species of higher plants (including ferns, gymnosperms and angiosperms), and it is important to note that the central mountain ranges in Hokkaido harbor many rare and endemic flora particularly in areas with serpentine rocks. For example, *Salix paludicola*, chickweed (*Stellaria pterosperma*), aconite (*Aconitum yamazakii*), and *Draba nakaiana* are endemic to Mt. Daisetsu. The flora of Mt. Apoi also contains by far the greatest number of endemics of Hokkaido, and is one of the most distinct among the serpentine communities of Japan. Some of the remarkable serpentine relics are *Hypochoeris crepidioides*, *Callianthemum miyabeanum*, *Crepis gymnopus*, *Rhamnus ishidae*, *Betula apoiensis*, *Viola hidakana*, and *Primula hidakana*.

(2) Mammals

Fig. 1-5. Lowland deciduous forest. A view in early spring (top: leaves of canopy trees are just opening), and a view of Sapporo City (bottom: the city is expanding by developing lowland deciduous forest established on the Ishikari depression)

There are approximately 62 species of mammals in this eco-region. These are mostly small mammals such as microbats, rodents, rabbits, and small mustelids. Red foxes (*Vulpes vulpes*) are also present. There is also an endemic subspecies of a more widespread Sika deer (*Cervus nippon yesoensis*) (Kamamichi 1996; Hilton-Taylor 2000). Japan's largest mammal species the Yezo brown bear (*Ursos arctos yesoensis*) is found only in this eco-region. The Yezo brown bear is considered a subspecies and is also found in the neighboring Russian controlled islands. The brown bear is an area-sensitive focal species for conservation planning as its population has restricted distribution in the lowland eco-region where they tend to overlap with human areas.

There is also an endemic sub-species of Pika (*Ochotona hyperborea yesoensis*) and Sable (*Martes zibellina brachyura*). Pika is a remnant of the glacial age and has a very narrow habitat range in the central mountains around Mt. Daisetsu. The Japanese sable is threatened by breeding with the Japanese marten (*Martes melampus*) introduced in Hokkaido.

(3) Birds

In Hokkaido, more than 400 species of birds are thought to habit and/or breed (Brazil 1991; Birdlife International 2000). A number of species found in Hokkaido is associated with northern latitudes and are not seen in the rest of Japan. These include vulnerable Stellar’s sea eagle (*Haliaeetus pelagicus*), white-tailed sea eagle (*Haliaeetus albicilla*), common merganser (*Mergus merganser*), tufted puffin (*Lunda cirrhata*), hazel grouse (*Tetrastes bonasia*), three-toed woodpecker (*Picoides tridactylus*), and willow tit (*Parus palustris*) (Higuchi et al 1995; Hilton-Tayler 2000). An endemic sub-species of hazel grouse (*Tetraste bonasia vicinitas*) is also found in Hokkaido (Higuchi et al. 1997).

Blakiston's fish owl (*Keputa blakistoni*) is a rare, endangered bird found in this eco-region. Its habitat-range is believed to be limited to the Hidaka mountain to Nemuro and the Shiretoko peninsula.

The endangered red-crowned Japanese crane (*Grus japonensis*) is considered a natural national bird and a symbol of happiness and longevity.

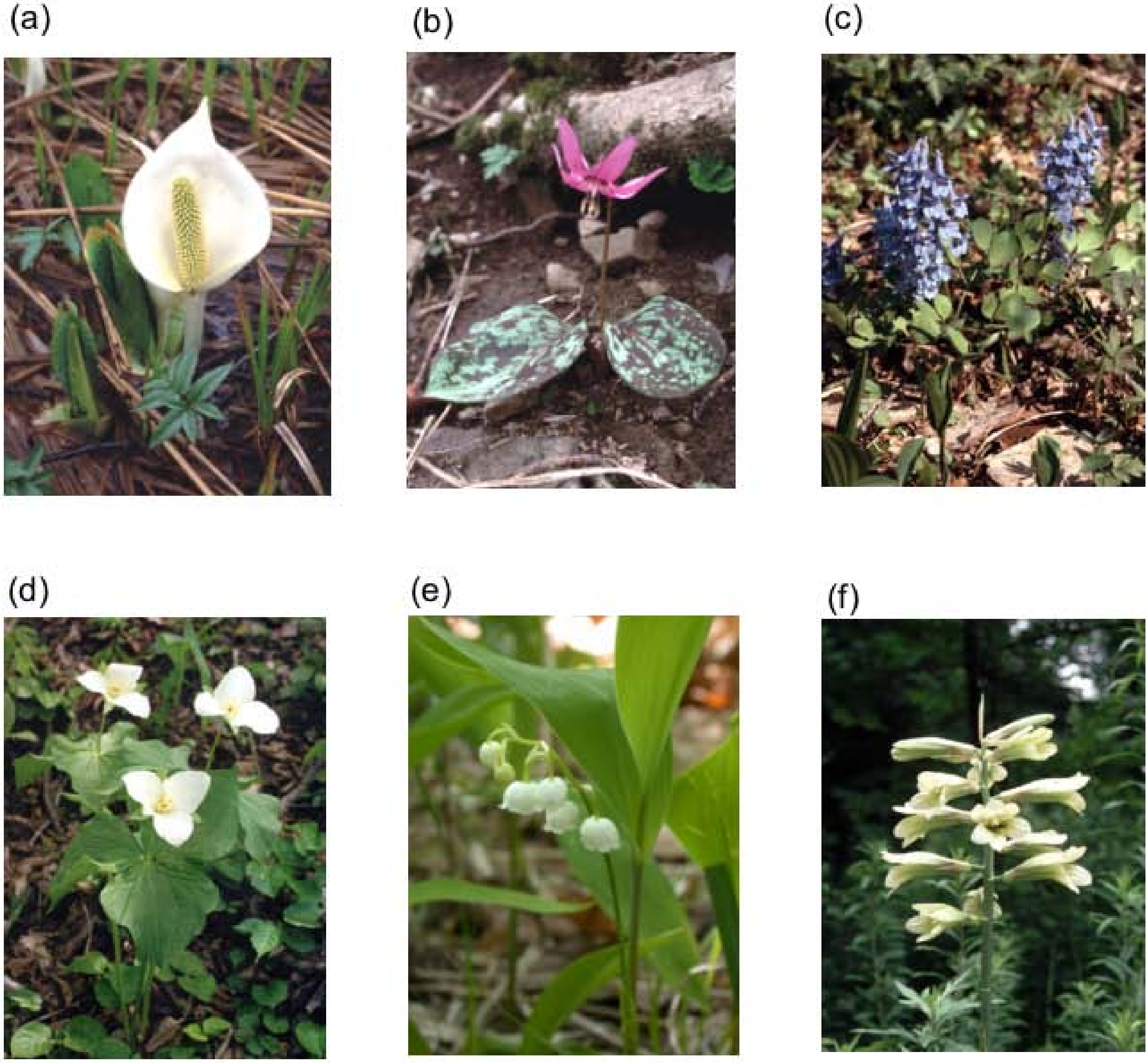

Fig.1- 6. Herbaceous plants in deciduous forests: *Lysichiton camtschatcense* (a), *Erythronium japonicum* (b), *Corydalis fumariifoia* (c), *Trillium camschatcense* (d), *Convallaria keiskei* (e), *Cardiocrinum cordatum* (f)

Hokkaido's red-crowned crane is a permanent resident of the lowland east coast of the island, whereas the mainland population of red-crowned cranes is migratory.

4. Importance of Conservation

(1) Factors responsible for extinction of wildlife

A variety of causes, independently or in concert, are responsible for extinction of wildlife. Historically, overexploitation was the major cause of extinction; although overexploitation is still a factor. Habitat loss is another major problem of today. Many other factors can contribute to species extinctions as well, including disruption of ecosystem interactions, pollution, loss of genetic variations, and catastrophic disturbances, either natural or man-made. The action of one factor predisposes a species to be more severely affected by another factor. For example, habitat destruction may lead to decreased birthrates and increased mortality rates. As a result, populations become smaller, and more fragmented and isolated making them more vulnerable to disasters such as floods or forest fires, and also to inbreeding. The loss of genetic variation through genetic drift, further decreases the population fitness. So, which factor causes the final *coup de grace* may be irrelevant as many factors and interactions between them may have contributed to a species' eventual extinction.

(2) What is happening in Hokkaido?

As mentioned above, Hokkaido is geographically, geologically and biologically interesting and unique island, and there is much precious wildlife including endemic species. However, after the rapid settlement of the Japanese in the Meiji era (1868-1912), natural forests were quickly replaced by farmlands and plantations, and some animal species such as the gray wolf and European river otter are now extinct. Tokachi plain in eastern Hokkaido, is a very active area for agriculture (adzuki bean, soybean, sugar beet and so on) and dairy farming. Anthropogenic land conversion (e.g. road construction and agricultural development) has resulted in highly fragmented landscape with a large number of forest remnants, many of which are smaller than 1 ha (Tan 1994)(Fig. 1-8).

Fig. 1-7. Mixed conifer-hardwood forest

Loss of habitat by a species frequently results not only in decrease in population, but also in fragmentation of the population into unconnected patches. A habitat may become fragmented in non-obvious ways, when roads and human habitation intrude the forest. This often results in disastrous consequences for wild life. The conservation status in Hokkaido is not satisfactory, and fragmentation of wildlife habitat is thought to be very substantial.

Habitat loss and degradation in the form of continued agricultural and industrial development constitute the principal threats to red-crowned cranes in Hokkaido. However, adoption of two active habitat management measures i.e. winter feeding stations and the installation of conspicuous markers on utility lines have allowed the Japanese red-crowned crane population to increase. These actions have reduced the rate of mortality from near extinction to approximately 60% (Swengel 1996).

Only 30% of the Blakiston's fish-owl nesting sites are protected within national parks or wildlife protected areas, and there is no regulation for general protection of the owl habitats. Well developed mixed forests have often been exploited for human establishments. Wild life has also been heavily affected by grazing by horses and cattle. Rapid decline in the population of endemic hazel grouse subspecies has been observed and it is probably due to the replacement of natural deciduous mixed forest with pine (*Larix leptrepis*) plantations for several decades.

Population of brown bears has been affected by hunting for sport and vehicular disturbances, but the greatest threat is the conversion of hardwood habitats into conifer plantations. Efforts directed at public education regarding human-bear interactions and the need to conserve and plan around bears' habitats have been identified as priorities.

(3) Harmony in agriculture and conservation

Development of agricultural fields and conservation of forests is antagonist to each other. However, we need to combine the both. Species populations in isolated patches may go extinct unless efforts are made to re-colonize these. It has become clear that isolated patches of habitat lose species far more rapidly than large preserves do. Corridors may assist dispersal between patches, and

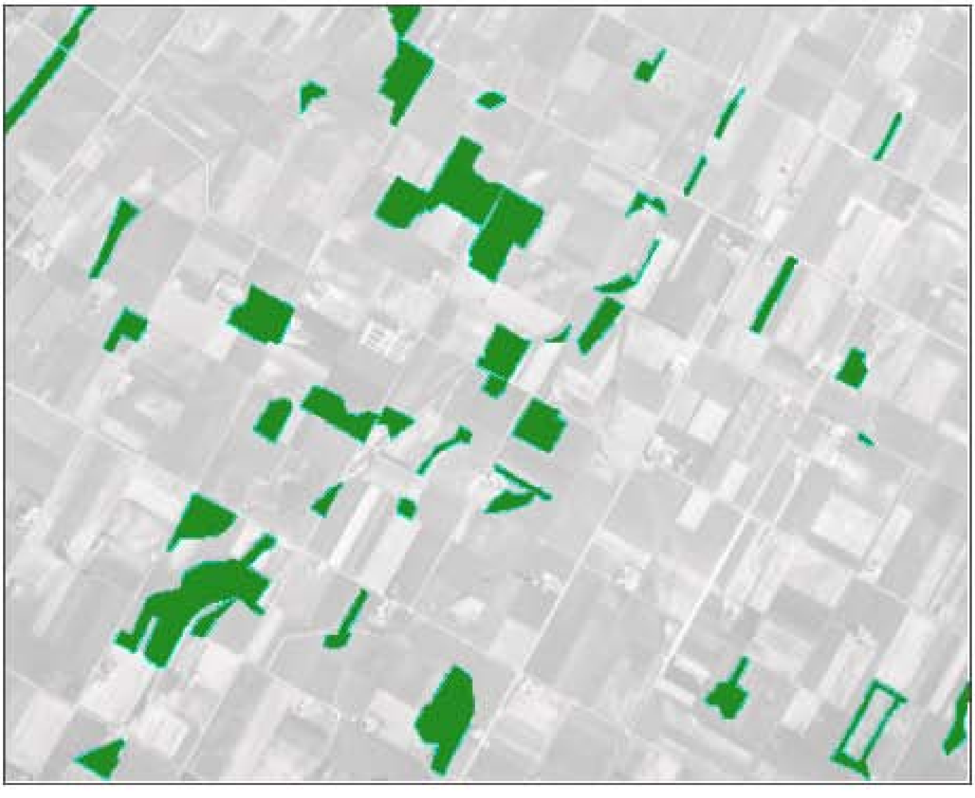

Fig. 1-8. A fragmented forest in sugar beet field (top) and various shapes of fragmented forests in agricultural area (bottom) in Tokachi Plain

maintaining connectivity among habitats has become one of the important features of conservation biology. Conservation biologists recently have promoted the criterion of so-called “mega-reserves”, large areas of land containing a core of one or more undisturbed habitats. The key to devoting such large tracts of land for long periods is that the operation of reserve should be compatible with local land use. Thus, while no economic activity is allowed in the core regions of the mega-reserve, the rest of the reserve may be used for nondestructive harvesting of resources i.e. sustainable resource harvesting. Linking reserved areas to carefully managed land zones creates a much larger total patch of habitat than would otherwise be economically practical, and thus addresses the key problem created by habitat fragmentation. Accordingly, joint management of biodiversity and economic activity is essential. The ecological challenge of conservation biology is to develop adequate management plans for individual species and ecosystem, whereas the challenge for the government is to broaden the movement so as to harmonize agricultural land use with conservation of natural habitats for wildlife in Hokkaido.

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Cultivation of field crops

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Chapter 2

Cultivation of Field Crops

Kazuto Iwama

1. History

(1) Until the middle of 19th century

In ancient days, local peoples called “Ainu” lived in Hokkaido. They originally came from the northern parts of Asia, such as Siberia and Karafuto, and they were mainly dependent on hunting. In the 16th century, so called “Japanese” governed by Tokugawa Shogun regime immigrated to the southern part of Hokkaido (Fig. 2-1), Matsumae, and established the domain of Matsumae. They used to export natural products such as seaweeds “Konbu” (Fig. 2-2), fishes and animal skins produced by local people of Hokkaido, and imported rice for staple food from main islands of Japan. Some fishermen and merchants, who generally visited coastal areas of Hokkaido during the summer, also used to cultivate vegetables in a small area near their residences. Although they wanted to cultivate rice, the cultivars introduced from the main islands did not grow well in Hokkaido because of cold climate.

In the 18th century, some foreigners mainly Russians used to visit some ports of Hokkaido, e.g. Hakodate and Kushiro (Fig. 2-1), and bought water and some vegetables. Potato was their favorite vegetable. As a result its cultivation increased in areas near the ports. A historical book written in the mid 19th century in Hakodate, reported more than 100 ha under potato cultivation in Hokkaido. Russians also introduced some potato cultivars to Hokkaido, e.g. ‘Kushiro-murasaki’, which is different from the present-day potato cultivars.

(2) Establishment of Meiji government

In the mid 19th century, the Tokugawa Shogun regime collapsed and the Meiji government governed throughout Japan including Hokkaido. The Meiji government established the Hokkaido Development Office, “Kaitakushi”, in

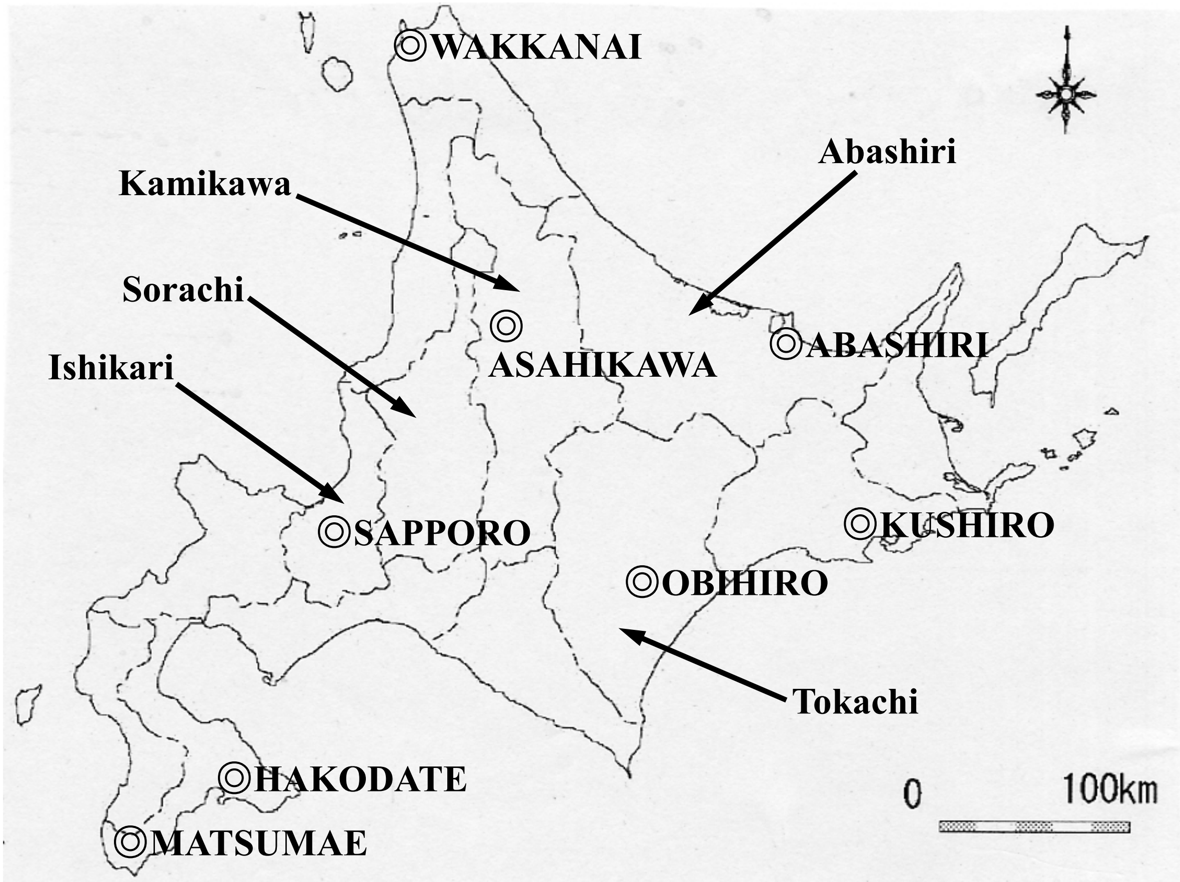


Fig. 2-1. Map of Hokkaido. Arrows; district name , Double circles; city name.

Fig. 2-2. Seaweeds "Konbu" exported to main islands of Japan.

Fig. 2-3. Central office of "Kaitakushi". (Historical Village of Hokkaido)

Hokkaido and set up its central office in Sapporo in 1869 (Fig. 2-3). The "Kaitakushi" enhanced immigration from main islands of Japan to Hokkaido; thus the population of Hokkaido increased rapidly (Table 2-1). From 1869 to 1936, about 3 million people immigrated to Hokkaido, and half of them were farmers. Some immigrants were called "Tondenhei", meaning the soldier for protection and cultivation of land (Table 2-2, Fig. 2-4). "Tondenhei" were mainly warriors ("Samurai") of defeated Tokugawa Shogun regime of Tohoku and Hokuriku areas of Honshu Island (Fig. 2-4). Some villages and cities of Hokkaido were named based on the places of origin of the immigrants in Japan.

"Kaitakushi" founded Sapporo Agricultural College (presently a part of Hokkaido University) in 1876, and invited professors from abroad, mainly from USA. The most famous professor was Dr. William Smith Clark, a former president of Massachusetts Agricultural College in USA. In 1878, he became the first vice-president of Sapporo Agricultural College, and inculcated a frontier spirit in young students coming from main islands of Japan. His words "Boys Be Ambitious", to the students when he left the college, became famous and show a frontier spirit. The students educated at Sapporo Agricultural College became leaders of Japan not only in agriculture but also in many other fields of high education and western thought. A few examples are Dr. Inazou Nitobe (pedagogy and economics), Mr. Kanzou Uchimura (philosophy and religion) and Mr. Takeo Arishima (literature).

(3) The spread of rice cultivation

The invited foreign professors studied the land and the climate of Hokkaido. They recommended an agriculture system similar to the North America, i.e. cultivation of upland field crops such as wheat and potato, and dairy farming. They considered that rice cultivation was not suitable for Hokkaido because of too cool climate. However, most of the immigrants from main islands of Japan did not like to change to a crop other than rice as a staple food. In addition, rice culms could also be used to produce winter snowshoes and ropes (Fig. 2-5). Because of the strong demand for rice by the immigrants including merchants and industry people, the market price of rice in Hokkaido was much higher than of other cereals. Therefore, farmers continued trials with rice cultivation. In 1873,

Table 2-1. Population in Hokkaido.

Year	Japan (million)	Hokkaido (million)	Ratio (%)	Note
1600	12	0.01	0.08	1)
1721	31	0.02	0.06	
1850	-	0.08	-	2)
1873	34	0.12	0.36	
1884	37	0.23	0.61	
1903	47	0.99	2.13	
1918	56	2.05	3.68	3)
1930	64	2.81	4.36	
1940	72	3.23	4.49	
1950	83	4.30	5.16	
1960	93	5.04	5.39	
1970	104	5.18	5.00	
1980	117	5.58	4.76	
1990	124	5.64	4.57	
1997	126	5.70	4.52	4)
2000	127	5.68	4.48	

1)The start of Tokugawa shogun regime.
2) The end of Tokugawa shogun regime.
The Meiji government started in 1867.
3) Fifty years since Kaitakushi opening.
4) The maximum population in Hokkaido.

Table 2-2. Cultivating area of field crops in Hokkaido (1000ha).

Year	Total	Rice	%	Upland crops
1882	20			
1894	38	3	8	35
1900	103	9	9	94
1910	224	35	16	189
1918	387	67	17	321
1919	402	73	18	329
1920	380	81	21	299
1930	473	187	40	286
1940	530	181	34	349
1950	402	144	36	258
1960	554	197	36	357
1967	539	247	46	293
1968	532	259	49	274
1969	531	266	50	265
1970	463	206	45	257
1980	445	154	35	290
1990	480	146	30	334
2000	424	135	32	289

Fig. 2-4. Clearing of forests land (top left figure), a village of "Tondenhei" (top right figure), and a farmhouse of Iwama family immigrated from Sendai district (left figure).
(Historical Village of Hokkaido)

Mr. Kyuzo Nakayama, an immigrant from Tohoku area and manager of a horse station at Shimamatsu near Sapporo, succeeded in selecting from the introduced cultivars of Tohoku area a rice cultivar ‘Akage’, which was tolerant to cool weather (Fig. 2-5).

In 1892, Mr. Tuneaki Sako, Head of the financial division in “Kaitakushi”, decided to enhance rice cultivation in Hokkaido and provided financial support for this. In 1886, “Kaitakushi” also established agricultural experiment stations throughout Hokkaido, and rice breeding was officially started. The breeders at the experimental stations initially practiced selection in cultivars introduced from the main islands of Japan, mostly from Tohoku area. In 1915, they started a pure line selection program to produce genetic purity for superior characteristics. The breeding by making crosses between the selected cultivars was started in 1913, just after the discovery of Mendelian laws by H. de Vries et al. in 1900. Using these methods, superior cultivars with high tolerance to cool climate and pests, and having high yield and adaptability to Hokkaido’s climate were progressively developed. As a result, rice cultivation rapidly increased throughout Hokkaido, and in 1930 it reached to about 200,000 ha with a total production of 432,000 ton and per capita availability of 150 kg, which was equivalent to per capita average of Japan (Table 2-3).

(4) The cultivation of upland field crops

In the northern and eastern parts of Hokkaido, i.e. Kitami, Abashiri and Tokachi (Fig. 2-1), rice cultivation could not be established because of very cool climate. Here, however, some upland crops such as potato and wheat achieved higher yield than in the main islands of Japan (Table 2-4).

In the early 20th century, Baron (“Danshaku” in Japanese) Kawata, president of a ship building company in Hakodate, imported many potato cultivars from Europe and USA to examine their adaptability in his experimental field near Hakodate. Among these, ‘Irish Cobbler’ bred in 1876 in USA, proved to be an early bulking and high yielding cultivar with good culinary quality. It was rapidly adopted by the farmers near his experimental field, who named it ‘Danshaku-imo’ (Baron potato, Fig. 2-6). Official potato breeding also started in the early 20th century at the Hokkaido Agricultural Experiment Station. Cultivar

Fig. 2-5. Memorial rice field at Shimamatsu (top figure), where Mr. Kyuzou Nakayama succeeded in selecting a rice cultivar 'Akage', and some products (mat and snowshoes) from rice straw (left figure).

Table 2-3. Rice cultivation in Japan and Hokkaido.

Year	Japan Area (1000ha)	Japan Yield (t/ha)	Japan Production (1000t/ha)	Hokkaido Area (1000ha)	Hokkaido Yield (t/ha)	Hokkaido Production (1000t/ha)	(%)	Note
1887				1.8	1.74	3		
1890				1.9	2.89	5		
1894	2664	2.34	6236	3.2	2.55	8	0.1	
1900	2731	2.24	6122	9.1	1.97	18	0.3	
1910	2834	2.42	6855	34.8	2.12	74	1.1	
1920	2960	3.11	9205	81.2	2.00	178	1.9	
1930	3079	3.18	9790	186.8	2.31	432	4.4	
1940	3004	2.98	8955	181.3	1.62	293	3.3	
1950	2877	3.27	9412	143.6	3.27	470	5.0	
1960	3124	4.01	12539	197.1	4.01	790	6.3	
1967	3149	4.53	14257	246.6	4.52	1114	7.8	1)
1968	3171	4.49	14223	258.6	4.74	1227	8.6	2)
1969	3173	4.35	13797	266.2	3.51	934	6.8	3)
1970	2836	4.42	12528	206.4	4.43	914	7.3	4)
1980	2350	4.12	9692	154.2	3.85	594	6.1	
1984	2290	5.17	11832	154.7	5.51	853	7.2	
1990	2055	5.09	10463	146.3	5.40	790	7.5	
2000	1763	5.37	9472	134.9	5.40	729	7.7	

1) The maximum production in Japan. 2) The maximum production in Hokkaudo.
3) The maximum cultivation area in Japan and Hokkaido.
4) The start of the policy for reducing rice cultivation.

‘Benimaru’ with high starch yield, and cultivar ‘Norin 1’ having high yield and resistance to late blight disease were released in 1937 and 1943, respectively (Fig. 2-6). These and cultivar ‘May Queen’ introduced in 1908 from UK were widely cultivated not only in Hokkaido but also in the other parts of Japan, and are still sharing about 50% of total potato area in Japan.

In the main islands of Japan, wheat is generally cultivated after harvesting rice. While in Hokkaido, it is cultivated mainly in upland fields, from September to August as winter wheat and from April to August as spring wheat. Since climate for the wheat cultivation in Hokkaido is different from that in other areas of Japan, many cultivars were introduced from Europe and North America to examine their adaptability in Hokkaido. In the early 20th century, a number of letters requesting seeds of wheat cultivars were written by Dr. Takajirou Minami, the first professor of Crop Science Laboratory in Hokkaido University. Official breeding of wheat was started in 1920 at the Hokkaido Agricultural Experiment Station, and many cultivars from crosses among imported cultivars were released. Cultivar ‘Akasabi-shirazu’ bred in 1927 was highly tolerant to red rust disease and was cultivated throughout Hokkaido. Cultivar ‘Norin 35’ bred in 1938 had hard grain and was thus suitable for bread making. Cultivar ‘Hokuei’ bred in 1954 had a very short culm and thus high tolerance to lodging. This enabled the use a large amount of chemical fertilizers and dense planting, resulting in a rapid increase in yield from 2.4-3.0 ton/ha to 4.2-4.8 ton/ha at the experimental level.

Hokkaido became a leading producer of several other crops also. Flax had been cultivated in Hokkaido in the late 19th century and exported to foreign countries as a raw material for fiber production. About two third of peppermint of the world was produced in Kitami area in the early 20th century. Although peppermint and flax are not cultivated now, farmers and related industries had earned a lot from their cultivation and this contributed for the progress of Hokkaido agriculture.

2. Present status

The area under field crops in Hokkaido is 640,000 ha, which is 13% of total area under field crops in Japan (Table 2-5). The number of farmers in Hokkaido is 52,000, about 3% of total number of farmers in Japan (Table 2-6). Thus the

Table 2-4. Cultivating area and yield of potato and wheat in Japan and Hokkaido.

	Potato				Wheat			
	Japan		Hokkaido		Japan		Hokkaido	
Year	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)
1887	16.4	6.5	2.3	9.9	387.2	1.08		
1897	28.6	7.6	10.2	10.7	454.4	1.15	1.9	1.43
1907	58.3	9.5	23.8	10.9	440.3	1.38	10.1	1.36
1916	102.7	10.2	57.9	11.0	527.6	1.53	16.5	1.23
1926	96.6	8.9	45.0	8.2	463.7	1.74	9.1	1.43
1930	103.0	10.1	45.2	9.4	487.4	1.72	13.5	1.62
1940	166.0	9.9	83.5	9.5	834.2	2.15	34.2	1.28
1950	192.4	12.7	75.5	15.1	763.5	1.75	29.8	1.32
1960	204.3	17.6	89.3	20.2	602.3	2.54	15.0	2.07
1970	158.8	22.7	69.8	31.0	229.2	2.07	11.7	1.03
1980	123.4	27.7	64.7	37.4	191.1	3.05	87.6	3.21
1990	115.8	30.7	67.5	38.5	260.4	3.65	120.9	4.14
2000	94.6	30.6	59.1	36.6	183.0	3.76	103.2	3.66

Fig. 2-6.　Display of potato varieties cultivated in Hokkaido.

'Irish Cobbler'; left side of top row, 'May Queen'; right side of second row, 'Benimaru'; left side of third row, 'Norin 1'; left side of bottom row.

(National Agricultural Research Center for Hokkaido Region)

average farm size in Hokkaido is about 20 ha, which is more than 10 times the average farm size in Japan, and almost equivalent to that in many European countries. Hokkaido is the top producer of both rice and many field crops in Japan. Mechanization has enhanced the efficiency of crop production. The status of each field crop in Hokkaido is explained in the following sections.

(1) Rice

Rice is cultivated on 119,000 ha of irrigated paddy fields in Hokkaido (Fig. 2-7), which is about 7% that of Japan (Table 2-7). In Hokkaido, rice is cultivated mainly in the central parts, i.e. Ishikari, Sorachi and Kamikawa (Fig. 2-1). Although Hokkaido is one of the most northern areas of the world cultivating rice, yet the yield level is high. Hulled grain yield in Hokkaido is 5.7 ton/ha, while the Japanese average is 5.3 ton/ha and the world average is about 2.5 ton/ha (Table 2-7). Presently, Hokkaido is the top producer of rice in Japan, contributing 8% of the total production.

Hokkaido has achieved an outstanding position in rice production as a result of continuous efforts for a long period since the Meiji period. By breeding improved cultivars and improving the cultivation methods, tolerance to cool weather has been enhanced (Fig. 2-8). Present-day rice cultivars of Hokkaido have much higher tolerance to cool weather than the old ones. In 1993, the unusual cool weather of Hokkaido caused a severe damage to rice growth, and the average yield was only 40% of the mean of previous five years. However, the reduction in yield was much smaller in the present-day cultivars than in the old ones (Fig. 2-9). Keeping in view the weather forecasts from agricultural extension centers, many farmers practiced water blanket method to maintain high level of water in fields and this protected young panicles containing infant flowers from low temperature (Fig. 2-10). Had the farmers not grown improved cultivars and followed improved cultivation method, they had harvested no grain in 1993. This could have led to a famine similar to those that occurred more than 50 years ago.

In the present decade, special attention has been paid to improve the eating quality of steamed rice of Hokkaido. It has been improved by two factors, breeding and climate change. The objective of rice breeding in Hokkaido has

Table 2-5. Agricultural land area in 2005.

	Japan	Hokkaido	Ratio
	(1000ha)		(%)
Total	4692	1169	25
Puddy field	2556	228	9
Upland field	2136	941	44
Field crops	1173	412	35
Fruit tree	332	3	1
Grass	631	525	83

Table 2-6. Average farm size of commercial farmers in 2005.

	Japan	Hokkaido	Ratio (%)
Land area (1000ha)	3447	966	28
Number of farms (x1000)	1963	52	3
Average Land area (ha)	1.76	18.59	1056

Table 2-7. Rice production in Hokkaido in 2005.

	Area (1000ha)	Products (1000ton)	Yield (kg/ha)
Japan total	1702	9062	5324
Hokkaido total	119	683	5731
Ratio (%)	7	8	108
Sorachi	54	318	5865
Ratio (%)	46	47	102
Kamikawa	31	184	5875
Ratio (%)	26	27	103

Fig. 2-7. Rice harvesting with combine in paddy field.

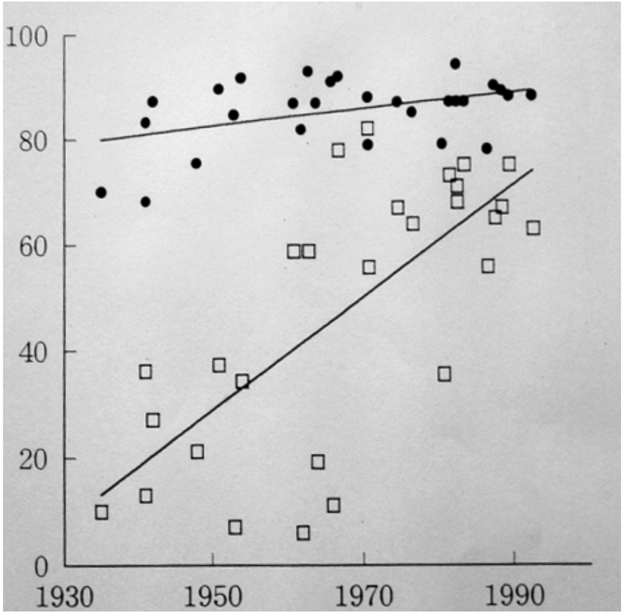
Fig. 2-8. Rice ears with fertile grain (left figure) and unfertile grains (right figure) at the end of growing season. (Photographs of Dr. T. Satake)

been changed since 1980s because of a rapid decline in the demand of rice in Japan. Rice production in Japan exceeded the consumption in 1970. Since then the Ministry of Agriculture, Forestry and Fishery (MAFF) has imposed restriction on rice cultivation (“Tensaku”, changing rice cultivation to other crops) throughout Japan (Table 2-3). Before 1970, the main objective of rice breeding in Hokkaido was to enhance tolerance to cool weather. Breeding to improve eating quality was paid little attention for a long period. As a result, the main cultivar ‘Ishikari’, which contributed about 60% of rice production in Hokkaido in 1970s had lower eating quality relative to the leading cultivars such as ‘Koshihikari’ and ‘Akita-komachi’ grown in the main islands of Japan. Therefore, the MAFF imposed the maximum restriction on cultivation of rice in Hokkaido, which accounted for about 50% of paddy fields. It resulted in a rapid reduction in rice area in Hokkaido, from 266,000 ha in 1969 to 135,000 ha in 2000 (Table 2-3).

To cope with the above situation, since 1980s, the rice breeding in Hokkaido has been targeted to improve the eating quality. Farmers’ union of Hokkaido contributed money to set up new and efficient equipments at the breeding stations of Hokkaido Agricultural Experiment Station to test the eating quality (mainly amylose content). As a result of these efforts by both researchers and farmers, a new rice cultivar ‘Kirara 397’ with improved eating quality was released in 1988. Its quality was, however, still lower than that of ‘Koshihikari’. However, because of low production cost resulting from large field size and mechanization of cultivation, ‘Kirara 397’ could be sold at a much cheaper rate than that of ‘Koshihikari’. This raised its popularity throughout Japan, especially at first food restaurants such as “Yoshinoya”. Since then, new cultivars such as ‘Hoshinoyume’, ‘Nanatsuboshi’ etc. with more superior quality have been released one after another in Hokkaido. The latest cultivar ‘Yumepirika’, released in 2008, has an excellent quality, equivalent or better than ‘Koshihikari’ grown in main islands.

Another factor that improved the eating quality of rice produced in Hokkaido is the change in climate, which is a global phenomenon. In general, the eating quality of rice depends on the proportion of amylose and protein, which control the stickiness and softness of steamed grains. The best combination for Japanese consumers is 16.5% of amylose and 6.0% of protein. Low

Percent of fertile grains



Released year of cultivar

Fig. 2-9. Relationship between the released year of cultivars and the percentage of fertile grains at Kitamura (open square) and Kamikawa (closed circle) in 1993. (Iwama et al. 1998)

Fig. 2-10. Paddy fields maintaining irrigation water at a high depth to protect the temperature decrease in the young panicle (left figure), and artificial climate regulation facilities to examine the mechanism of cool weather damage in rice panicles (right figure) at the Kamikawa Agriculture Experiment Station. (Photographs were provided by Dr. H. Tanno)

temperature during the ripening period of grain from August to September in Hokkaido frequently restricts the decrease of amylose and protein in grains. However, global climate change has caused some increase of temperature in summer and autumn. This has helped the cultivars with improved eating quality to express their full genetic performance. In the southern parts of Japan, on the contrary, summer temperature sometimes exceeds those required for normal grain development and thus results in lower quality. It is hoped that Hokkaido will become a leading rice producer area of Japan in the next decade not only for quantity but also for quality of rice produced.

(2) Wheat

Wheat is cultivated in116,000 ha in Hokkaido, which is 54% of total area of wheat in Japan (Table 2-8). In Hokkaido, wheat is mainly cultivated in the northern and eastern parts i.e. Kitami, Abashiri and Tokachi (Fig. 2-1), where it is cultivated in upland fields. Wheat is also cultivated in paddy fields in the central part of Hokkaido i.e. Ishikari, Sorachi and Kamikawa (Fig. 2-1).

Average yield (4.7 ton/ha) of wheat in Hokkaido is much higher than in the other parts of Japan (3.4 ton/ha). It contributes 62% of total wheat production of Japan. Two types of wheat, winter wheat and spring wheat are grown in Hokkaido. Winter wheat is sown in the first fortnight of September. Before snow fall, the plants grow to 10 cm and have 6 to 8 leaves (Fig. 2-11). After snow fall, snow-cover protects the plants from severe low temperature of winter. Snow melts in April and the plants start growing again, and reach the heading stage in early June. The harvesting is done from late July to early August. The development of improved high yielding cultivars at the Hokkaido Experimental Station has led to a rapid increase in wheat production in the current decade. The latest cultivar ‘Kitahonami’ (Fig. 2-12) has high grain quality comparable to Australian Standard Wheat (ASW), which is suitable for making Japanese noodles. This cultivar was released in 2007, and its hulled grain yield recorded more than 10 ton/ha in farmer’s fields.

Spring wheat is sown after snow melts in April. It grows rapidly, reaches the heading stage in late June, and is harvested in mid August. As spring wheat gets much shorter growth period than winter wheat, the average yield (hulled grain) of

Table 2-8. Wheat production in Hokkaido in 2005.

	Area (1000ha)	Products (1000ton)	Yield (kg/ha)
Japan total	214	875	4097
Hokkaido total	116	540	4676
Ratio (%)	54	62	114
Tokachi	46.2	231.2	5004
Ratio (%)	40	43	107
Abashiri	26.2	148.2	5656
Ratio (%)	23	27	121
Sorachi	15.6	61.3	3929
Ratio (%)	14	11	84
Kamikawa	12.7	44.3	3488
Ratio (%)	11	8	75

Fig. 2-11. Winter wheat field in Tokachi in late autumn.

Fig. 2-12. High yielding winter wheat cultivar 'Kitahonami' at the ripening stage.

Fig. 2-13. Drill seeding machine (top figure) and harvester (bottom figure) used in wheat cultivation at big farms in Hokkaido.
(Bottom figure was provided by Prof. Y. Shibata of Hokkaido Univ.)

spring wheat in Hokkaido is about 30 ton/ha. However, spring wheat has high protein content and thus there is a strong demand for this from bread makers. Presently, spring wheat shares less than 10% of wheat area in Hokkaido, mainly in the central part, i.e. Ishikari and Sorachi. In these areas, early winter sowing ("Syotou-maki") of spring wheat is increasing. The spring wheat is sown just before snow fall in late autumn, and it germinates just after snow melting in early spring. Since the growing period becomes slightly longer in early winter sowing relative to general spring sowing, the yield increases about 20%. The latest cultivar 'Harukirari' released in 2007 has high grain quality almost comparable to the imported Canadian wheat used for bread making, and it is expected to increase the spring wheat cultivation in Hokkaido.

The cultivation of wheat in Hokkaido is fully mechanized as in Europe. Seeding is done with a drill planter and harvesting with a combine (Fig. 2-13). The average labor requirement of wheat is about 30 hours per ha, which is the lowest among field crops in Japan.

(3) Potato

Potato being adapted to cool climate is cultivated in all areas of Hokkaido. Hokkaido has 56,000 ha of potato, sharing 64% of potato area in Japan (Table 2-10). Average potato yield in Hokkaido is much higher (39 ton/ha of fresh tubers) than in other parts of Japan (20 ton/ha); thus Hokkaido contributes 78% of Japan's potato production.

Depending on the usage, three types of potatoes are cultivated in Hokkaido: table potatoes (for household usage), processing potatoes (for chips and French fries), and starch potatoes (for starch), with 16, 22 and 47% of potato area of Hokkaido, respectively. The leading cultivars for table potato are 'Danshaku-imo' and 'Kitaakari', for processing are 'Toyoshiro' and 'Sayaka', and for starch production is 'Konafubuki' (Fig. 2-6). Presently, the production of starch potatoes is decreasing because of severe competition with the imported potato starch and corn starch, which are cheaper. On the other hand, the production of processing potatoes is increasing because of the increase in consumption of chips and French fries, especially by young generations.

Hokkaido is also famous for the production of seed tubers. The National

Table 2-9. Potato production in Hokkaido in 2005.

	Area (1000ha)	Products (1000ton)	Yield (ton/ha)
Japan total	87	2749	31.6
Hokkaido total	56	2151	38.6
Ratio (%)	64	78	122
Tokachi	23.6	831	35.2
Ratio (%)	42	39	91
Abashiri	18.2	730	40.1
Ratio (%)	33	34	104
Shiribeshi	4.5	136	30.7
Ratio (%)	8	6	79
Kamikawa	3.4	119	35.0
Ratio (%)	6	6	91

Fig. 2-14. Propagation of virus-free seedlings in-vitro condition (top figure) and microtubers produced from transplanted seedlings (bottom figure) at the National Center for Seeds and Seedlings in Hokkaido.

Fig. 2-15. Planting of seed potato (top left), cultivation of rows to prevent weeds (top right), spraying of pest sides (bottom left) and harvesting (bottom right) of potato in Hokkaido. (Left figures were provided by Prof. Y. Shibata)

Center for Seeds and Seedlings (NCSS) is producing seed tubers at four farms located at Shiribeshi, Kitahiroshima, Iburi and Tokachi in Hokkaido (Fig. 2-14). The tubers produced at these farms are sold to progressive farmers, who propagate the seed tubers under the inspection of the Plant Protection Office of MAFF. Only these farmers are permitted to sell their potato produce as seed tubers to other farmers. The seed tubers produced in Hokkaido are used not only in Hokkaido but also in the other parts of Japan.

Mechanization of potato cultivation is progressing in Hokkaido. Planting and harvesting are done with automatic machines attached to big tractors (Fig. 2-15). The average labor requirement of potato cultivation is 100 hours per ha, and only about 50 hours per ha for production of starch potatoes in big farms.

(4) Beans

Three kinds of beans, soybean, adzuki bean and kidney bean (Fig. 2-16, Fig. 2-17), are cultivated in Hokkaido on a total area of 60,000 ha comprised of 28,000 ha with soybean, 23,000 ha with adzuki bean and 9,000 ha with kidney bean (Table 2-10). Although beans are sometimes damaged by cool weather, they enrich soil by nitrogen fixation in their root nodules. Therefore, their cultivation is useful as it helps to maintain wheat-potato-sugar beet crop rotation system for 4 years in upland fields in Hokkaido.

Hokkaido contributes 23% of total soybean production of Japan (Table 2-11). In Japan, soybean is generally cultivated in lowland fields used for rice cultivation. In Hokkaido, however, soybean is cultivated in both low land fields and upland fields. Tokachi is the main area of soybean cultivation in upland fields accounting 22% of total soybean area of Hokkaido. Soybean yield in Hokkaido is 2.5 ton/ha, which is much higher than an average of 1.5 ton/ha in the other parts of Japan. The present leading cultivar of soybean is ‘Yukihomare’ bred in 2001. It has a determinate growth habit and large grain size (about 350 mg). The grains are mainly used for traditional Japanese foods, such as “tofu” (soybean pudding) and “Natto” (fermented soybeans) (Fig. 2-17), and brewing of “miso” (soybean paste) and “shoyu” (soy sauce). A special cultivar ‘Suzumaru’, of very small grain size (about 100 mg), is used for making “Natto”.

Adzuki bean originated in Japan and is cultivated only in Hokkaido. Japanese

Table 2-10. Cultivating area and yield of beans in Hokkaido.

Year	Soybean Area (1000ha)	Soybean Yield (t/ha)	Azuki bean Area (1000ha)	Azuki bean Yield (t/ha)	Kidney bean Area (1000ha)	Kidney bean Yield (t/ha)	Total Area (1000ha)
1894	8.8	1.72	15.4	1.05	1.8	1.94	26.0
1900	29.2	1.66	30.1	1.60	9.5	1.66	68.8
1910	76.9	1.23	52.1	1.29	13.6	1.56	142.6
1920	102.0	1.33	53.5	1.33	57.9	1.08	213.4
1930	80.2	1.49	46.7	1.51	91.5	1.45	218.4
1940	85.5	0.84	40.5	0.86	90.3	0.92	216.3
1950	86.1	1.41	19.6	1.40	33.1	1.38	138.8
1960	68.0	1.59	60.5	1.63	78.0	1.68	206.5
1970	10.0	1.62	43.8	1.55	67.5	1.75	121.3
1980	23.1	1.65	29.9	1.26	20.0	1.50	73.0
1990	12.7	2.60	40.4	2.38	20.3	1.48	73.4
2000	16.2	2.66	30.0	2.53	11.3	1.21	57.5
2006	28.1	2.49	22.8	2.46	8.9	2.03	59.8

Table 2-11. Soybean production in Hokkaido in 2005.

	Area (1000ha)	Products (1000ton)	Yield (kg/ha)
Japan total	134	225	1679
Hokkaido total	21	52	2483
Ratio (%)	16	23	148
Kamikawa	5.0	12.0	2424
Ratio (%)	23	23	98
Tokachi	4.7	13.3	2824
Ratio (%)	22	25	114
Sorachi	4.5	11.0	2428
Ratio (%)	21	21	98

Fig. 2-16. Soybean at the ripening stage.

Fig. 2-17. Grains of soybean (top left), adzuki bean (top right) and several kinds of kidney beans (bottom).

Fig. 2-18. Traditional Japanese foods made from soybean grains, Tofu (left) and Natto (right).

call this “Adzuki”, because of its small grain size. Adzuki bean is used to make festive red rice and bean jam. The leading adzuki bean cultivar is ‘Erimoshozu’. The yield and quality of Japanese adzuki bean are much higher than the imported adzuki bean, which is mainly from China. However, Hokkaido’s adzuki bean is more than 7 times expensive than the imported ones. The annual variation in yield is large because of variation in damage due to cool weather. The need thus is to assure stable production and reduce the cost of production.

Compared with wheat and potato, there is little mechanization of bean cultivation, particularly for harvesting (Fig. 2-19). As a result, the average labor requirement, for example of soybean cultivation is more than 100 hours per ha. This results in much higher price of soybean produced in Hokkaido compared to the imported ones, mainly from USA and Brazil. The use of harvester specially modified for beans is increasing in big farms of Tokachi and Ishikari.

(5) Sugar beet

Sugar beet (Fig. 2-20) is cultivated on 69,000 ha in Hokkaido, and there is no area under sugar beet in other parts of Japan (Table 2-12). The average yield is 53 ton/ha, which is as high as in Europe. It is used to produce sugar under protection of the Japanese government. Sugar beet area is mainly in the northern and eastern parts of Hokkaido i.e. Tokachi and Abashiri (Fig. 2-1). In these areas many factories to produce sugar from sugar beet are located.

The sowing method of sugar beet in Hokkaido is typical. To regulate the number of plants per hill, seedlings are first grown in paper pots in a nursery bed and then transplanted in fields. This also reduces weeds. The transplanting is partly mechanized, but complete mechanization is needed to reduce the production cost. Although the yield of the crop grown from direct seeding is about 20% lower than that in the transplant-crop, direct seeding with seeding machines is increasing to reduce the production cost. Improvement in seeding methods and development of cultivars adapted to direct seeding is underway.

Fig. 2-19. Drying the harvested soybean (Niozumi in Japanese) in fields before threshing.

Table 2-12. Beet production in Hokkaido in 2000.

	Area (1000ha)	Products (1000ton)	Yield (ton/ha)
Japan total	69	3673	53.1
Hokkaido total	69	3673	53.1
Ratio (%)	100	100	100
Tokachi	30.6	1637	53.5
Ratio (%)	44	45	101
Abashiri	27.4	1531	55.9
Ratio (%)	40	42	105
Kamikawa	4.6	232	50.2
Ratio (%)	7	6	95

Fig. 2-20. Sugar beet field in early autumn at Kitami.

Cultivation of Horticulture Crops

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Chapter 3

Cultivation of Horticulture Crops

Hajime Araki

1. Fruits

Fruits have a lot of nutritional elements, anti-oxidants, vitamin C and dietary fibers, which inhibit cancer-inducing substances. These also contain K which promotes Na release for maintaining blood pressure. The Japanese government has published guidelines, stating the importance of eating at least 200 g of fruits everyday for good health. This standard can be fulfilled by eating either one piece of apple or a cluster of grapes or 40 pieces of cherry or one piece of pear or 7 pieces of prune or 2 pieces of orange a day.

Fruit farming in Hokkaido was started upon the advice of Horace Capron, the Commissioner and Adviser to the Development Commission. Many kinds of saplings were imported mainly from United States. Primary fruit trees were apple, grape and cherry, which were grown mainly in the southern (Nanae), and central Hokkaido (Yoichi, Niki, Sohbetsu, Mashike and Takikawa) (Fig. 3-1, 3-2). Fruit acreage, mainly of apple, peaked to about 7,000 ha in the 1960's. Subsequently, it decreased and was only 3,152 ha in 2004. This was due to the disease valsa canker, freezing damage, urban sprawl and decline in the market price. Acreage of grapes remained comparatively stable. On the other hand, cherry acreage increased to 630 ha; 1.6 times of that in 1990 (Fig. 3-3). Many orchard farmers in Hokkaido have been trying modern methods including growing dwarf trees of apple and cherry for saving physical labor, building greenhouses for early harvest of grapes and putting plastic sheet roofs for preventing cracking of cherry fruits due to rain. These days many consumers visit orchards to enjoy fruit picking and buy fresh fruits, especially apple, cherry, grape, blueberry etc.

(1) Apple

Apple cultivars bloom in second half of May, and fruits are harvested from August to November (Table 3-1). In Honshu island, the main island of Japan, 'Fuji' is the most popular cultivar. Over 50% of total apple production is in Honshu Island. In Hokkaido, many other apple cultivars are also grown. There, 'Fuji' is not the main cultivar.

Fig. 3-1. Main fruit trees produced in Hokkaido
1.Apple ('Hacnine')
2.European pear ('Brabdy wine')
3.Cherry ('Nanyo 2')
4.Grape ('Cambell early')
5.Blueberry
6.Honey berry (haskap)

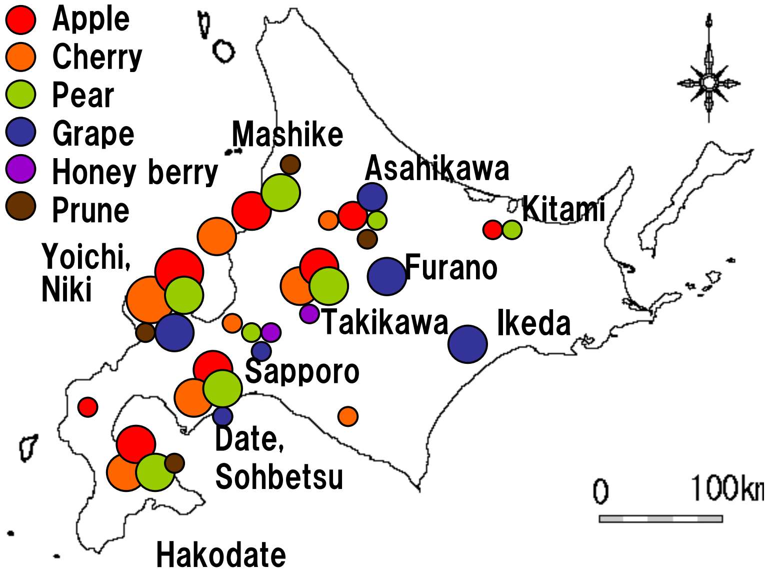

Fig. 3-2. Production area of main fruit trees in Hokkaido

Table 3-1. Harvest season of apples in Hokkaido

Month	Cultivars
August	'Natsu-no-beni', 'Natsu-no-mai'
September	'Kitakami', 'Tsugaru'
October	
early	'Sansa', 'Akane', 'Senshu', 'Jonathan',Himekami',
middle	'Red gold', 'Golden delicious', 'New jona gold', 'Hacnine',
late	'Orin', 'Mutsu'
November	'Fuji'

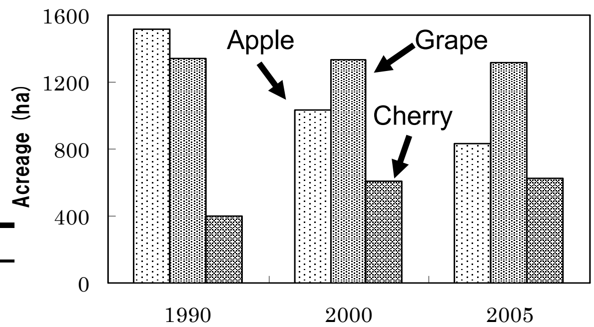

Fig.3-3. Change of production acreage in apple, grape and cherry in Hokkaido

Fig.3-4. Dwarf apple. Grafting with dwarf root stock in apple nursery production(1). Lodging of dwarf apple tree by typhoon because of poor root system(2).

In general, fruits of early harvested cultivars are sour and can not be stored for long time. ‘Tsugaru’, a typical middle harvest cultivar, produces big and sweet fruits. ‘Hacnine’ (Hokkaido Apple Clone No. 9) that had originated in Hokkaido, was established by the Hokkaido Central Agricultural Experimental Station in 1985. Approximately 93% of the apples are sold fresh and only remaining 7% are used for processing, mainly for juice and jam.

Rootstocks M9, M26 and JM7 etc. have been used for production of dwarf trees. Dwarf trees are convenient for spraying fungicides and pesticides, pruning, training and also for harvesting of fruits (Fig. 3-4). These can also be planted at higher density. However, due to their week rootstock, some dwarf apple trees fell down during typhoon no.18, which attacked Japan in 2004 with a wind velocity of more than 40 m/s.

(2) Cherry

Although cherries are more expensive compared with other fruits, yet these have been popular among many consumers. Cherries are harvested from early July to early August. Some famous cultivars such as ‘Sato-nishiki’, ‘Beni-shyho’ and ‘Nanyo’ etc. are very sweet, and their price can be more than 1,000 yen/kg. A new cultivar named ‘June Bride’ has been developed by the Hokkaido Central Agricultural Experimental Station. This cultivar is harvested in late June, fairly earlier than other cultivars. It also has higher tolerance to low temperature. It sets well by pollination with almost all cultivars that are grown in Hokkaido. In order to protect cherry fruits from cracking by rains, cultivation of cherry under poly-tunnels (of height more than 2.5 m) is increasing (Fig. 3-5). Besides, dwarf cherry is gradually spread by using dwarf root stock (Fig. 3-6).

(3) Grape

In Hokkaido, grapes production per year is 10,000 t of which 38% is processed into wine and juice. The main cultivars for fresh use are ‘Delaware’, ‘North-black’, ‘North-red’, ‘Buffalo’, ‘Portland’, ‘Niagara’ and ‘Tabiji’, while ‘Seibel 13053’, ‘Seibel 5279’, ‘Kerner’, ‘Muller Thurgar’ and ‘Zweigelt Rebe’ are mainly processed into wine. Hokkaido has the highest grape production for wine in Japan. There are many wineries, big and small, near grape farms in Hokkaido. Gibberellin is sprayed on grape wines for production of seedless grapes, especially of early cultivar ‘Delaware’.

Fig.3-5. Field work for cherry production. 1. Working with extension Ladder. 2. High tunnel for rain shelter.

Fig.3-7. Fruit of raspberry (1), haskap (2) and cherry (3).

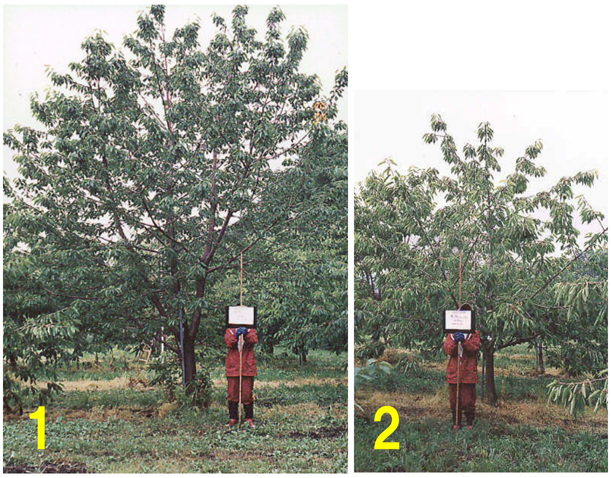

Fig.3-6. Dwarf production in Cherry. 1. Cherry tree grafted with ordinary root stock cultivar ‘Colt’ 2. dwarf tree grafted with ‘Chishima’ .

Table 3-2. Change of Production acreage of main vegetable in Hokkaido

Vegetables	Production Acreage (ha)		
	1,990	2,000	2,005
Japanese radish	5,410	5,090	4,390
Carrot	5,680	6,410	5,140
Chinese yam	1,490	1,890	2,130
Cabbage	1,870	2,800	1,680
Welsh onion	801	1,100	868
Onion	11,700	12,800	11,600
Asparagus	4,540	2,330	1,850
Broccoli	474	683	1,680
Pumpkin	6,620	8,080	8,090
Sweet corn	14,500	9,940	8,780
Tomato	459	687	780
Melon	2,030	2,020	1,610

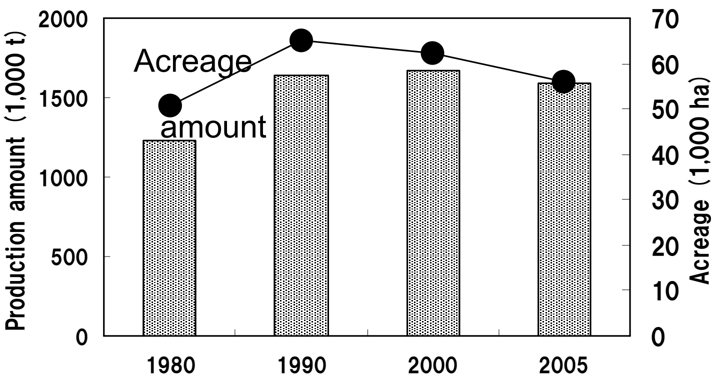

Fig.3-8 Change of production Acreage and production amount of vegetable produced in Hokkaido

Table 3-3. Change of production acreage of vegetables produced in greenhouse and high tunnel, Hokkaido

Vegetables	Acreage (ha)		
	1990	2000	2005
Tomato	152	424	575
Cucumber	136	127	130
Welsh onion	49	174	134
Strawberry	105	123	117
Watermelon	286	140	181
Melon	592	1093	1079
Spinach	445	703	740

4) Other fruits

Prune, blueberry and honeyberry (haskap) are gaining popularity among health conscious Japanese. Honeyberry locally called ‘haskap’ had originated in Hokkaido. Production of blueberry, raspberry and honeyberry is increasing as these are used for cakes (Fig. 3-7). Honeyberry grows wildly in Hokkaido. Farmers cultivate the plants collected from mountains. However, harvesting of honeyberry is labor intensive because of the small size and soft texture of the mature fruit. Hokkaido University has been carrying out selection of individual plants from native honeyberries to breed cultivars with bigger and tastier fruits.

2. Vegetables

The cool climate in summer and autumn has made Hokkaido the main supplier of vegetables. The vegetable production accounted for 15.4% of total agricultural production in Hokkaido. Approximately 70% of vegetables produced in Hokkaido are transported to other islands in Japan. Hokkaido can be proud of its high share in Japan’s vegetable production: onion (51%), sweet corn (23%), carrot (24%), Japanese radish (11%), Chinese yam (29%) and melon (15%) （Table 3-4）.

The acreage of vegetables has been expanding in Hokkaido since 1970 (Fig. 3-8). In 1995, area and production of vegetables reached a maximum of 66,000 ha and 1,876 t, respectively. Area under major vegetables was: Japanese radish: 5,400 ha, carrot: 5,700 ha, onion: 12,000 ha, pumpkin: 6,600 ha and sweet corn: 14,500 ha (Table 3-2). However, due to labor shortage and low sale price in 2006, area and production reduced to 55,000 ha and 1,592 t, respectively. Compared to 1995, the production of Japanese radish, cabbage and sweet corn reduced, whereas that of Chinese yam (Nagaimo), pumpkin, tomato and broccoli increased. In recent years, vegetable production has been stable and valued at 1,600-1,700 billion yen, which accounted about 8% of total vegetable production in Japan.

Use of greenhouses (GH) and high tunnels (HT) are increasing, and these covered an area of 2,900 ha in 2005 (Table 3-3). The average area of GH and HT per farm is about 20 a. Tomato, cucumber, welsh onion, strawberry, watermelon and spinach are mainly produced in GH and HT.

(1) Onion

Growing of onions in Japan started in Sapporo in 1871 on a trial basis. On

Table 3-4. Comparison of output of vegetable produced in Hokkaido and other prefectures

Vegetable	Output (Billion Yen)			
	Total	1st	2nd	3rd
Onion	73.2	Hokkaido 37.0	Hyogo 8.5	Saga 7.8
Sweet corn	30.9	Hokkaido 7.2	Chiba 3.9	Ibaraki 2.5
Carrot	60.8	Chiba 15.4	Hokkaido 14.7	Tokushima 6.6
Japanese radisl	106	Chiba 14.2	Hokkaido 14.3	Kanagawa 9.7
Chinese yam	44.9	Aomori 14.9	Hokkaido 13.1	Chiba 3.9
Melon	90.2	Ibaraki 18.4	Hokkaido 13.9	Kumamoto 13.2

Fig. 3-10. Harvest and washing of carrot, Otofuke Town, eastern Hokkaido

Fig.3-9. Onion production 1,2.Growing of Seedlings with plastic tray in plastic tunnel from March to May. 3.Planting machine. 4. Growing of onion plant in summer. 5,6. Mature of onion bulb and under-cutting before harvest for effective drying on the field. 7,8. Harvest of onion bulb and storage in September. 9. Clean up of bulb for marketing.

commercial basis production began in 1878, after the success of the cultivar ‘Yellow Globe Danver’. Later, this became the ancestor of modern Hokkaido cultivars. In 2005, onion’s acreage was11,600 ha.

Cultivars’ choice depends on the growing season i.e. spring or autumn. In Hokkaido, onion is grown during spring. Seeds are sown in late February or early March, transplanted in May and harvested in September. Onion cultivation is completely mechanized from sowing to harvest, and also packing (Fig. 3-9). The Hokkaido Agricultural Experimental Station has developed a new onion cultivar 'Quer rich', which has higher content of quercetin than the ordinary cultivars. Quercetin has anti-thrombus effect.

(2) Carrot, Japanese radish and Chinese yam

These vegetables are mainly produced in the Tokachi region of eastern Hokkaido. Carrots as well as radish are harvested, and also washed and packed using automatic machines (Fig. 3-10).

Seed tubers of Chinese yam are planted in May and harvested in October-November (Fig. 3-11). Chinese yam has sticky texture, which is good for various traditional Japanese foods. This vegetable can be stored for a long period at low temperature and is transported to Honshu Island and exported to south-eastern Asian countries.

(3) Cabbage and welsh onion

Cabbage is also mainly cultivated in Tokachi region. Nurseries are grown in greenhouses and transplanted by planter. However, harvesting is done manually (Fig. 3-11).

Welsh onion is one of the traditional materials for Japanese food. Usually, welsh onion is added to noodles such as soba, udon etc. The nursery of welsh onion is transplanted by a unique planter and ridging is performed 2 or 3 times until harvest to produce white leaves. This activity is called ‘blanching cultivation’ (Fig. 3-11).

(4) Pumpkin

Pumpkin is popular among people of all ages. However, its cultivation involves tedious activities such as arranging lateral shoots and harvesting in large fields. To solve such problems, a new cultivar named ‘TC2A’ (commercial name ‘Hottoke Kuritan’) with short internodes and fruiting at lower nodes has been developed by the National Agricultural Research Center for Hokkaido

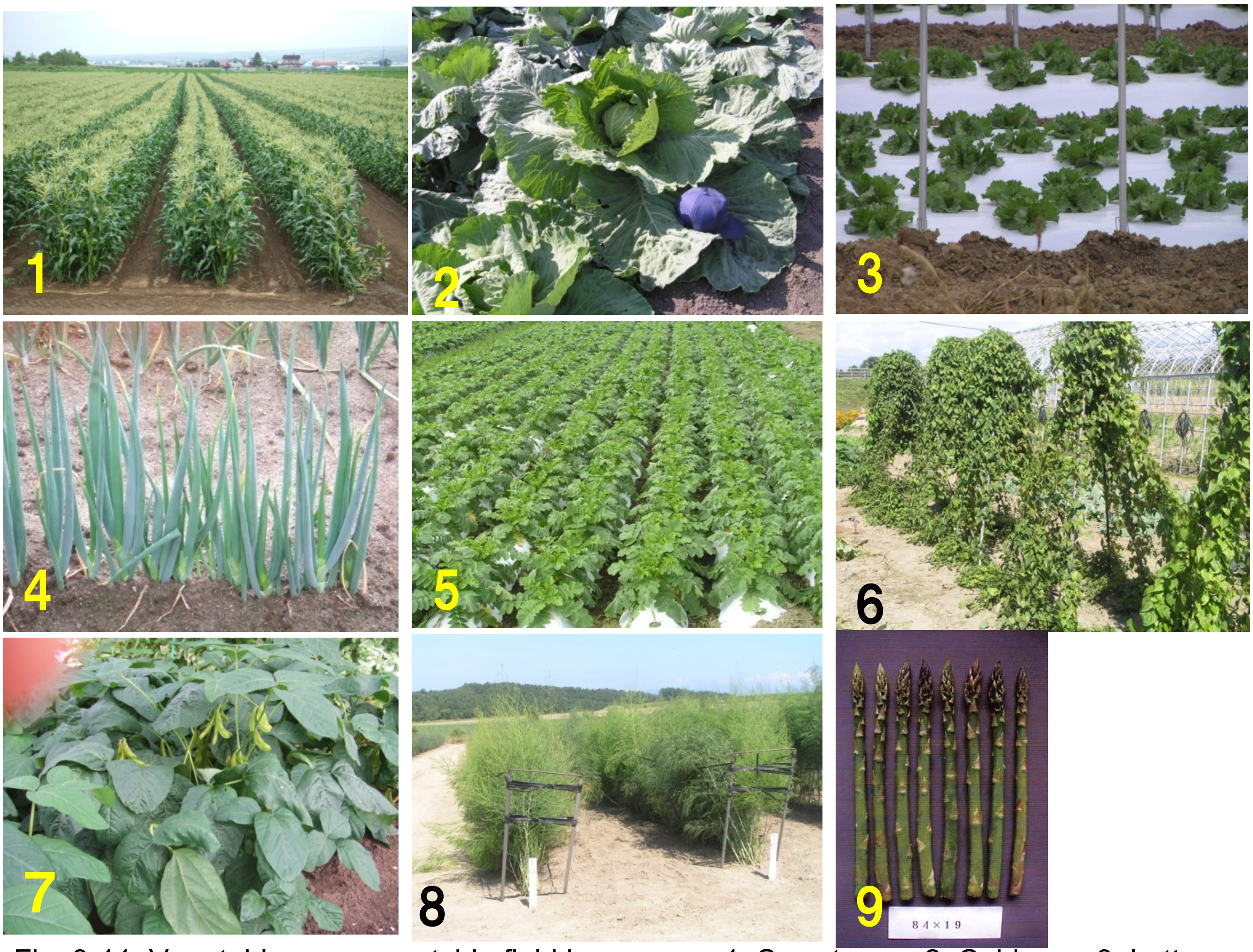

Fig. 3-11. Vegetables grown outside field in summer. 1. Sweet corn, 2. Cabbage, 3. Lettuce, 4. Welsh onion (banching onion), 5. Japanese radish called ‘Daikon’, 6. Yam called ‘Nagaimo’ 7. Immature soybean called ‘Edamame’ 8,9. Asparagus , Hokkaido University established a new cultivar named ‘Yujiro’, with cooperated with National Agricultural Research Center for Hokkaido Region and Hokkai Can Co., Ltd.

Fig. 3-12. Melon and watermelon produced in Hokkaido
1. Orange-colored melon 2,3. Ordinary and black peel-watermelon

Region.

(5) Asparagus

Though asparagus is an important vegetable of Hokkaido, its acreage has decreased remarkably after the 1990's. Asparagus if grown continuously on the same field for years, its productivity decreases. Thus it needs to be replanted in new fields. Since this involves time and money, which are constrains for the traditional farmers who have gone old now, little replanting has been undertaken.

The production of green asparagus, however, is increasing as new cultivars were imported from United States and Europe (Fig. 3-11). Long-term harvesting of asparagus by cultivating in high tunnels has been established. The production of green asparagus is higher than its demand, whereas the demand for white asparagus for use as salad is increasing.

(6) Strawberry

Strawberry cultivars are of two types: i) flowering only for short period and ii) those flowering nearly through out the year. Almost all cultivars in Japan flower for short period. Strawberry is harvested from December to April in Honshu islands and from May to June in Hokkaido. In summer, a large amount of strawberry is imported. For strawberry production both in summer and autumn, all season flowering cultivars such as 'Pechika' and 'HS183' are now cultivated in Hokkaido. These are planted from May to July. Now strawberries are grown on high beds for comfortable work (Fig. 3-13). Strawberries are mainly used for cakes.

(7) Melon and watermelon

Melon is one of the symbolic fruits of Hokkaido. In 2003, melon was cultivated on 1,760 ha. The cultivar called 'Spicy' came from the United States in 1922. A hybrid between 'Carter's Earl's Favourite' and 'Spicy' was developed by the Hokkaido Agricultural Experimental Station in 1935. It became the base cultivar of Hokkaido. 'Yubari King', the most popular brand in Japan, is one of its progenies. It has orange and soft flesh (Fig. 3-12). Large quantities of delicious melons are produced in Hokkaido and transported to all over Japan from July to September. Unique watermelon with black peel and red fresh is cultivated around Iwanai town (Fig. 3-12).

Fig. 3-13. Strawberry in high tunnel. 1. Nursery 2, 3. Production by low bed and high bed. 4,5,6. Many fruits attacked in one cluster and fruit thinning for large fruit production.

Fig. 3-14. Tomato production and tomato fair. 1.Grafting in young seedling 2.Training of tomato plant in high tunnel. 3. Growing tomatoes. 4,5. Hand packing of tomato 6. Automatically packing of small size tomatoes. 7. Tomato fair held at supermarket. 8. Middle size tomato for cooking. 9. Harvest season of processing tomato

(8) Tomato

Tomato is produced in glasshouses and high tunnels in order to prevent their damage by rain (Fig. 3-14). Previously, tomatoes were harvested about 7 days before full maturity in order to maintain their hardness and freshness till these reach consumers. But these tomatoes used to loose their original flavor and taste. Now tomato cultivars, such as “Momotaro” have been developed, which are good enough to maintain their hardness, freshness, as well as flavor and taste for some duration even when these are harvested at their full maturity. These cultivars are becoming very popular.

Main production areas of tomatoes are near Hakodate, Takikawa and Biratori. Processing of tomatoes into juice, and as boiled etc. is increasing Tomato fair is held for commercial purpose every year.

Hokkaido now has the policy to promote ‘Clean Agriculture’, which is friendly to environment. The objective is to reduce the use of chemicals and fertilizers, so as to produce safe agricultural products. In vegetable production, plastic mulch or plant residue mulch is used for effective weed control, and net covering is used for pest control (Fig. 3-15). Farmers who do not use chemicals and fertilizers can label their products as ‘Yes Clean’ (Fig. 3-16).

3. Flowers

(1) History of flower production

Flower cultivation in Hokkaido started in 1875 when an American, Lewis Barman, planted 74 foreign species in a greenhouse at Sapporo Agricultural School. In those days, flowers were also grown in some parks. After World War II, the demand for flowers increased. Farmers living near the cities began growing flowers. After 1960’s, with rapid economic growth, the flower production increased. In 1965, cut-flower production became one of the substitutes to rice cultivation. Since 1975, ‘Baby’s Breath’ of Hokkaido has received maximum nationwide awards. Hokkaido supplies large shipment of cut-flowers to other prefectures from summer to autumn. Flower production is also carried out as a part-time job by rice farmers.

(2) Flower calendar in Hokkaido

Main flowers produced in Hokkaido are shown in Fig. 3-17 and Fig. 3-18. Cut-flowers are produced mainly from May to November except Alstroemeria

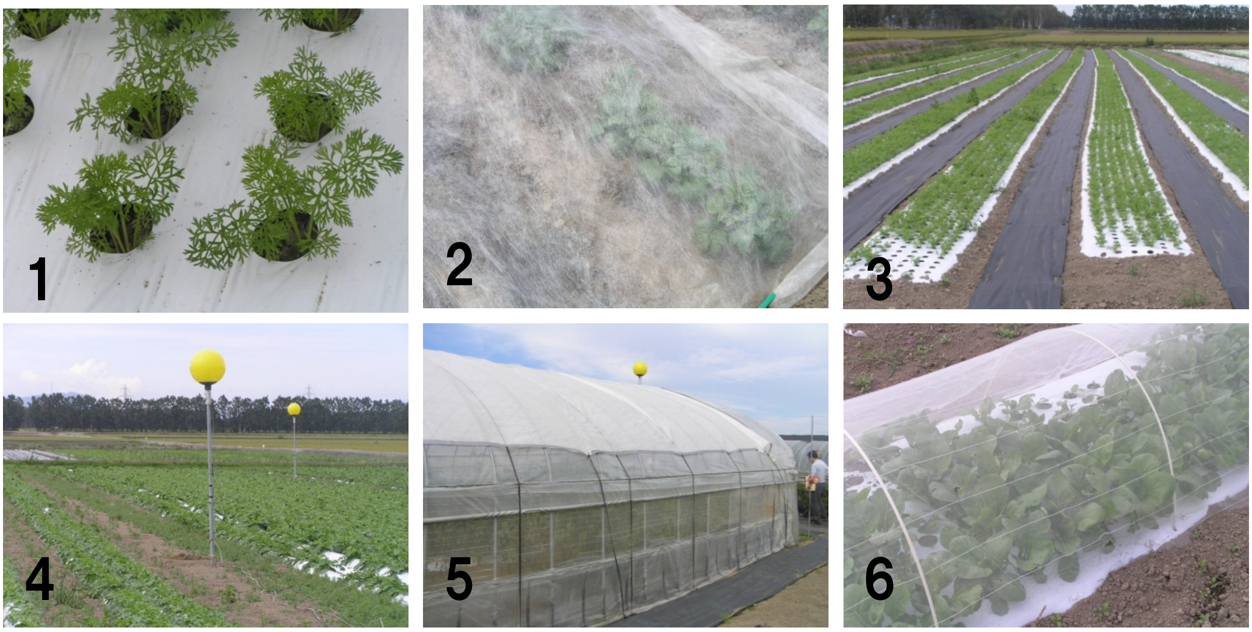

Fig. 3-15. Some materials for reduction of application of agricultural chemicals. 1. Mulching of plastic film 2. Covering by non-woven fabric at juvenile stage 3. Black sheet for controlling weeds 4. Yellow light for confusing flight of moth. 5, 6. Setting of net for protecting from some insets

Fig. 3-16. Yes! Clean label certificated as the vegetable production with reduced fertilizer and agricultural chemicals(1). Green manure plants are incorporated to modify of soil properties before vegetable production (2).

Fig. 3-17. Main flowers produced in Hokkaido. 1.New lily cultivar named ‘Kita-kirari’, 2,3. Alstroemeria, 4. Prairie gentian, 5. Carnation, 6. Cyclamen

and Freesia, both of which have year-round production (Table 3-5). Farmers grow seedlings for cut-flowers in greenhouses or high tunnels in winter and transplant them in early spring. Some farmers transplant them in winter itself for forced production.

Cool summer weather of Hokkaido allows farmers to supply flowers to other prefectures where it is still off-season. The climate of Hokkaido gives flowers a vivid color, thereby creating a huge demand for theses in Honshu. Shipments from Hokkaido in July-September, 2005 accounted for 60% of the 174 million yen cut-flowers production in Japan in that year. In 2005, in Hokkaido flowers were grown on 694 ha and production earned 12.9 billion yen, of which 72% was from cut -flowers, and 18% from potted flowers and seedlings (Table 3-6).

Some companies have large greenhouses (Fig. 3-21) with modern facilities for regulating temperature, humidity and nutrition etc. Expensive flowers like orchids and fruits with high quality can be produced under these conditions. However, their running and maintenance cost is too high (Fig. 3-21).

(3) New cultivars and technology

1) Lily cultivar

Hokkaido Ornamental Plants and Vegetables Research Center in Takikawa city, has developed a new lily cultivar ‘Kita-kirari’ in 2002 (Fig. 3-17). This cultivar produces small flowers. The petal is vivid reddish-orange with small dark-brown spots. The inflorescence is compact raceme, and thus this cultivar is suitable for Japanese traditional flower arrangement ’Ikebana’, and small bouquets. This cultivar produces more cut-flowers per unit area than other lily cultivars because of its numerous branches.

2) Wet-transporting system

Maintenance of freshness in cut-flowers is important, especially, while transporting them by trucks (73% of total transportation) from Hokkaido to big cities in Honshu islands. In order to achieve this a small space in which water is stored is set in each packing case so that cut-flowers are able to absorb water and remain fresh (Fig. 3-18). A chemical solution ‘PAT’ (Plant Active Technology), is added to vases to prolong the life of cut-flowers.

3) Cultivation under artificially prolonged days

Long-day treatment has been used to control flowering time in

Table 3-5. Production season of main flowers in Hokkaido

Flower		Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cut	Baby's breath					○	○	○	○	○	○	○	
	Carnation					○	○	○	○	○	○	○	○
	Statice					○	○	○	○	○	○	○	
	Prairie gentian						○	○	○	○	○	○	
	Arstromeria	○	○	○	○	○	○	○	○	○	○	○	○
	Lily					○	○	○	○	○	○	○	
	Stock					○	○	○	○	○	○	○	
	Antirrhuim					○	○	○	○	○	○	○	
	turip	○	○	○	○	○							
	Freesia	○	○	○	○	○	○	○	○	○	○	○	○
	Color					○	○	○	○	○	○		
	Rose				○	○	○	○	○	○	○	○	○
	Delphynium					○	○	○	○	○	○	○	
	Cosmos							○	○	○	○		
	Sun flower						○	○	○	○	○		
	Sweet pea				○	○	○	○	○	○	○	○	
	Gladiolus							○	○	○			
	Sunder sonia							○	○	○	○	○	
Potted	Cyclamen										○	○	○
	Poinsettia										○	○	○
	Primrose	○	○	○	○	○							
	Lavender					○	○	○					
	Lily of the valley					○							

Fig. 3-18. Flower production and baby's breath in wet transportation. 1.Tulips in box, 2.Statics, 3.Lily, 4.Prairie gentian, 5.Carnation, 6. Wet transportation

Chrysanthemum. This technique was adapted in Delphinium and *Prairie gentian* flowers in autumn in Hokkaido. 'Long-day treatment' elongates inter-nodes of Delphinium. In Prairie gentian, the same technique prevents blasting of the flower buds and helps them have fine blooms.

4) Flower parks

There are many flower parks in Hokkaido: Lily park in Sapporo, Lavender park in Furano, Tulip park in Kami-yubetsu, moss phlox in Takinoue, Sunflower park in Hokuryu and English style garden in Uni town (Fig. 3-19).

(4) Future

The flower production in Hokkaido has been growing and these are produced all over Hokkaido. However, these days demand of cut-flowers is unstable due to recession, spread of flower production in the whole country and increase in imported flowers etc. On the other hand, the demand of flowers for home-gardening and room decoration is increasing. In order to stabilize the demand, it is important to have access to the marketing information and an efficient distribution system. These days, many events are organized for exchanging information among farmers, consumers and designers etc. (Fig. 3-20).

Acknowledgement

I would like to thank to Mr. Yutaka Inagawa, Fruit tree section, Hokkaido Central Agricultural Experiment Station, Mrs. Ryoko Suzuki, Ornament Plant Section, Hokkaido ornamental plant and vegetable research center and Mrs. Naho Murata, Local crop breeding research team, National Agricultural Research Center for Hokkaido Region for their suggestions and photographs.

Fig. 3-19. Flower garden in Hokkaido. 1,2.Lavender and Salvia (Furano city)
3,4. Yuni garden (Yuni town), 5,6. Marygold and sunflower (Nakafurano town)

Fig. 3-20. Festival of baby's breath for expanding of production and consumption.

Table 3-6. Change of production acreage in flowers in Hokkaido

Flowers	Production acreage (ha)		
	1990	2000	2005
Cut flower	421	700	629
Potted flower	15	34	21
Seedlings for garden	14	50	44
Flower farmer	2,737	2,402	1,946

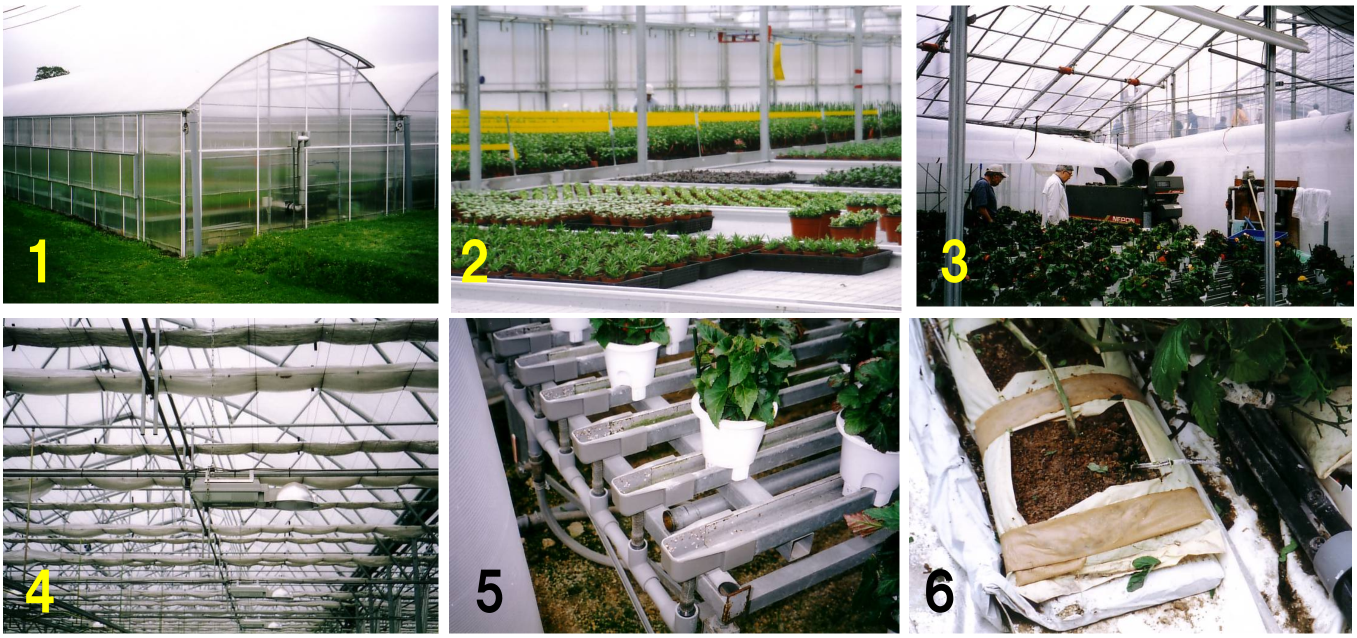

Fig. 3-21. Modern facilities. 1 Plastic high tunnel with roof, 2. Moving bench, 3.Warm duct, 4.Filter for shading, 5. Liquid fertilizer application, 6. Tomato production with drip irrigation.

Forage crops

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Chapter 4

Forage Crops

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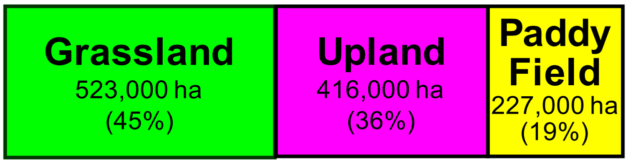
Grassland farming is one of the important activities in Hokkaido's agriculture. Grasslands cover 45% of cultivated area of Hokkaido. About 83% of the grasslands of Japan are in Hokkaido alone (Fig. 4-1). In eastern and northern Hokkaido where rice cultivation can not be undertaken due to cool climate, dairy farming based on grasslands is the major agricultural activity. It accounts for 91.5% of the total agricultural output. Size of dairy farms in these districts is comparable to those of European countries. Grasslands in Hokkaido consist of perennial forage grasses such as timothy and orchardgrass, and perennial forage legumes such as white clover, red clover and alfalfa. In upland areas such as Tokachi district, maize is grown as an annual forage crop for use as silage for animal feed. In this chapter, forage crops cultivated in Hokkaido are described.

1. History of Hokkaido's grasslands

The cultivation of forage crops in Hokkaido was first recorded in 1869. Gaertner, a Prussian (now German), cultivated some forage crops in Nanae near Hakodate. At the Sapporo Agricultural College (now Hokkaido University) the cultivation of forage crops whose seeds had been imported by Dr. William S. Clark from Massachusetts, USA was started in 1877. Dr. Edwin Dun (Fig. 4-2), who has been called the father of Hokkaido's dairy farming, established the Makomanai Livestock Farm in 1876. In 1887, forage crops were cultivated at several livestock farms in Hokkaido. In those days, forage grasses such as timothy and orchardgrass were grown in grasslands. Timothy was grown mainly for production of hay for use as feed of horses. Orchardgrass was used for both hay production and grazing by cattle. However, after the World War II, due to decrease in horse population cultivation of timothy declined. In 1955, the grassland area was only 80,000 ha. During 1960's, the consumption of animal



Cultivated area of Hokkaido 1,166,000ha
(25% in Japan)

Fig.4-1. Cultivated area in Hokkaido.

Fig.4-2. Edwin Dun Memorial Museum at Makomamai, Sapporo. The materials used at Makomanai Livestock Farm in those days are displayed.

products such as milk and meats increased drastically due to the influence of western life-style and economic development. After 1956, grasslands were developed on a large scale in eastern Hokkaido with the support of Japanese government and World Bank. So called 'Pilot Farm Program' was carried out using big machinery to develop grasslands. Later, a number of grasslands were established every year, which had an area over 500,000 ha by the end of 1980's (Fig. 4-3). In the 1970's, for the establishment of grasslands in the eastern Hokkaido near Abashiri, orchardgrass was cultivated, because of its high forage yield. But, in 1975, severe winter conditions of the region killed orchardgrass plants in many swards. Subsequently, cultivation of timothy, a winter hardy species, was undertaken in this region, and now it covers more than 70% of the grasslands of Hokkaido. Timothy has high forage quality and is a suitable feed for high milk yielding cows (super cow); thus it is a preferred forage crop for grasslands.

2. Forage crops

Table 4-1 shows the current acreage of forage crops in Hokkaido. Perennial forage crops as well as annual maize are important for forage production in Hokkaido.

(1) Perennial forage crops

Timothy and orchardgrass are cool season grasses. These are cultivated as important perennial forage crops in Hokkaido. Hokkaido has two distinct climate zones. During winter, the western Hokkaido has thick snow cover (non-frozen soil zone); thus orchardgrass and perennial ryegrass are grown there. The eastern Hokkaido has less snow cover (frozen soil zone). Here winter hardy species such as timothy and meadow fescue are common (Fig. 4-4). Perennial forage legumes such as red clover, white clover and alfalfa are usually cultivated as a mixture with grasses. They play an expanded and invaluable role in the nitrogen economy, animal productivity and sustainability of grasslands.

Main perennial forage crops grown in Hokkaido are listed below.

1) Timothy:

Fig. 4-3. Grassland in the eastern Hokkaido -view from an observatory point, 'Kaiyou-dai' in Nakasibetsu-town.

Table 4-1. Acreage of forage crops in 2006 (ha).

	Japan	Hokkaido
Forage grasses & legumes	787,300	569,700
Maize	85,200	36,600
Sorghum	34,300	158
Oat & Rye	62,080	45,618
Forage turnip	339	0
Others	27,381	10,024
Total	996,600	662,100

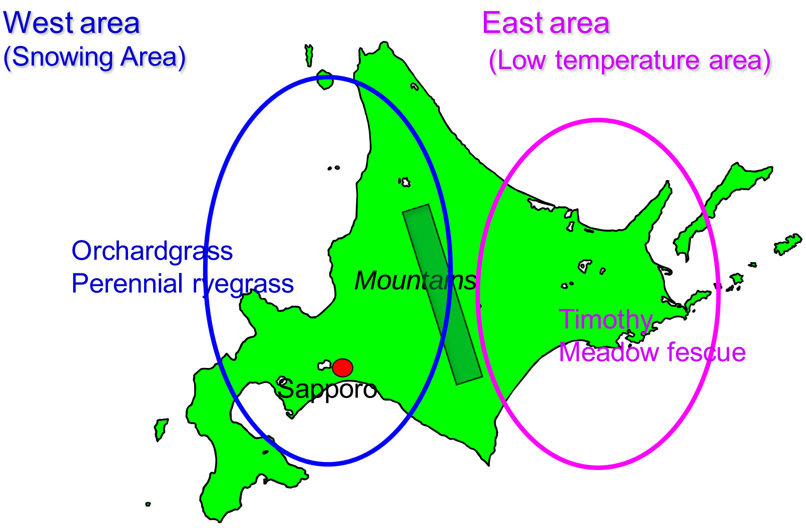


Fig. 4-4. Two different climate conditions in winter and distribution of cultivated grasses.

Scientific name: *Phleum pratense* L.

Japanese name: Oh-awagaeri

Timothy (Fig. 4-5) is the most important grass in the Hokkaido region and now occupies more than 70% of Hokkaido's grasslands. This species is well adapted to humid and temperate area with severe winters, and thus does not grow under dry or hot conditions. Timothy is one of the most winter-hardy cool-season grasses. LT_{50} (the temperature at which half of plants are killed) was lower than -25^{o}C for samples of timothy collected in December (Fig. 4-6). Thus timothy can be cultivated steadily in the coldest areas of the eastern Hokkaido. It is used mostly for hay and silage. Timothy has high palatability and forage quality. However, it has poor re-growth after cutting. It is not suitable for grazing pasture. It is very compatible with red clover.

In the past, early flowering cultivars of timothy had been popular in Hokkaido. Delayed harvest due to simultaneous heading and flowering often results in lower forage quality. Forage quality reduces drastically after flowering. Therefore, intermediate and late flowering cultivars of timothy have been developed. Now cultivars with different maturity periods are available (Fig. 4-7). Thus, now a farmer can harvest timothy grasslands at the optimal time.

2) Orchardgrass (Alias: Cocksfoot)

Scientific name: *Dactylis glomerata* L.

Japanese name: Kamogaya

Orchardgrass (Fig. 4-8) is well adapted to humid and temperate regions. It has moderate tolerance to heat and drought, and higher shade tolerance than most of other forage grasses. LT_{50} of orchardgrass is higher than that of timothy (Fig. 4-6). It can not survive severe winters of the eastern Hokkaido. Orchardgrass shows high yield and good response to fertilizers. It has relatively good palatability and forage quality. Orchardgrass is used primarily for hay and grazing pasture. It is compatible with alfalfa, white clover and red clover.

Area under orchardgrass in Hokkaido has declined in the past three decades because of its relatively poor winter hardiness and decrease in the

Fig. 4-5. Timothy.

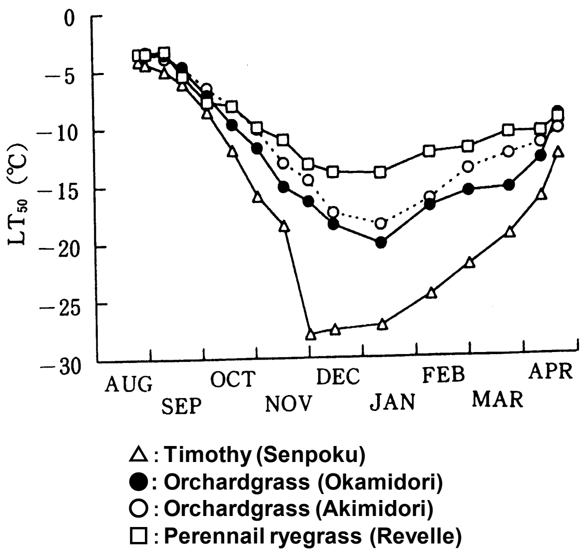


Fig. 4-6. LT_{50} (the temperature at which half of plants is killed) in three species of grasses.

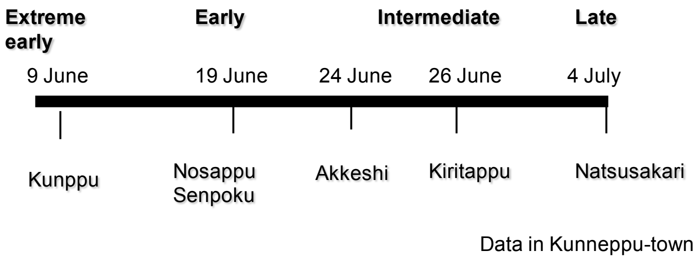


Fig. 4-7. Ear emergence in timothy cultivars released at the Hokkaido Pref. Kitami Agric. Exp. Station.

forage quality resulting from delayed harvest. However, recently orchardgrass has gained attention due to its high productivity and earlier heading time compared to timothy. Keeping in view the growing periods of timothy and orchardgrass, grasslands with a combination of these two may result in high herbage production.

3) Perennial ryegrass

Scientific name: *Lolium perenne* L.

Japanese name: Hoso-mugi

Perennial ryegrass (Fig. 4-9) is the most important grass species in western Europe and New Zealand. In Hokkaido, its use as forage has been limited to the northern Hokkaido, Tenpoku area which is a non-frozen soil zone due to heavy snow cover. It does not tolerate low fertility, drought and heat stress, as well as severe winters of eastern Hokkaido. LT_{50} of perennial ryegrass is substantially poorer than that of timothy and orchardgrass (Fig. 4-6). This species has high digestibility and palatability as well as resistance to treading by grazing animals. It is grown in gazing pasture mainly as mixture with white clover, but is also used for hay and silage production.

4) Meadow fescue

Scientific name: *Festuca pratensis* Huds.

Japanese name: Hiroha-no-ushinokegusa

Meadow fescue (Fig. 4-10) has characteristic good re-growth after cutting and winter survival. This species is generally grown mixed with orchardgrass and timothy as a companion crop in Hokkaido. However, this is also a promising grass for grazing pasture in eastern Hokkaido where cultivation of perennial ryegrass is difficult.

5) Alfalfa (Alias: Lucerne)

Scientific name: *Medicago sativa* L.

Japanese name: Murasaki-umagoyashi

Alfalfa (Fig. 4-11) is called ‘Queen of forage’ because of its good forage quality and high protein content. It does best on soil with fine to medium

Fig. 4-8. Orchardgrass.

Fig. 4-9. Perennial ryegrass.

Fig. 4-10. Meadow fescue.

textures that are moderately to well drained and neutral or alkaline. It tolerates drought and is very winter hardy. Alfalfa is well adapted in the USA. However, it is not adapted so well in Hokkaido due to acidic and wet soil conditions. But breeding has led to the development of cultivars adapted to Hokkaido conditions. New cultivars, 'Makiwakaba' and 'Haruwakaba' have shown good performance in Hokkaido region and area under these cultivars has increased. Mono-cultivation as well as mix-sowing of alfalfa with grasses such as orchardgrass is practiced. Alfalfa is mainly used for silage production. It is not suitable for grazing.

6) White clover

Scientific name: *Trifolium repens* L.

Japanese name: Shiro-tsume-gusa

White clover (Fig. 4-12) is the most important forage legume for mix-sowing in temperate grasslands of the world. It is well adapted to humid temperate climate. White clover is grown throughout Hokkaido. Cultivars are classified for leaf size: small (wild), medium (common) and large (ladino). Small types are dwarf and have very prostrate habit, and are not very productive. These are used for intensive grazing pasture. Medium types are intermediate in size between small and large types, and are used for silage or grazing pasture. Ladino types have larger leaves and longer petioles, and are more productive. These are used for hay and silage production.

7) Red clover

Scientific name: *Trifolium pratense* L.

Japanese name: Aka-tsume-gusa

Red clover (Fig. 4-13) is a short-lived perennial forage legume widely distributed in temperate grasslands. It has good winter hardiness, but poor tolerance to high temperature and drought. This species is grown throughout Hokkaido. Cultivars are classified into two growth habits, medium and mammoth. Medium types flower earlier and produce two or three harvests, while mammoth types flower much later and typically produce a single harvest. Red clover has high palatability and nutritive value. Its poor persistence (only

Fig. 4-11. Alfalfa.

Fig. 4-12. White clover.

Fig. 4-13. Red clover.

two to three years), however, is disadvantageous. It is used for hay and silage production, and also for grazing.

8) New forage species

A new forage legume ‘Galega” (*Galega orientalis* Lam.) has been recently introduced from Estonia and registered as a recommended forage cultivar for Hokkaido (Fig. 4-14). This species shows good persistency and high adaptability under mixed cultivation with timothy in Hokkaido. However, it has slow establishment, which needs to be improved through breeding.

(2) Annual forage crops

In Japan, corn (maize) and sorghum are important annual forage crops. Maize is grown mainly in Hokkaido in an area of 36,600 ha. It is mainly cultivated on uplands in the Tokachi district. In Hokkaido, sorghum is grown in a very limited area because it requires warm temperature in summer. Rye and oat are also cultivated as forage crops, but currently their acreage is not large. Therefore, only corn is described here.

1) Corn (Alias: Maize)

Scientific name: *Zea mays* L.

Japanese name: Toumorokosi, Toukibi

Corn (Fig. 4-15) is world’s third leading cereal crop, after rice and wheat. However, unlike rice and wheat, corn is consumed mainly as feed for livestock rather than as human food. Corn is often classified into six groups based upon endosperm characteristics. These are dent, flint, flour, pop, sweet and waxy corns. Sweet corn has high sugar in kernels and is grown for human consumption. Dent and flint corns are mainly used for animal feeds. About 40% of the world’s corn is grown in the USA, and mainly (over 90%) for grain. But in Japan including Hokkaido, corn is cultivated for the production of silage. The whole plants are harvested when kernels are in yellow-ripe stage. All commercial cultivars are hybrids. Mainly early maturing (75-110 days) hybrids are grown because in Hokkaido accumulated temperatures during growing season (16 May–10 Oct) are low (2,000 – 2,500 ^{o}C). In eastern Hokkaido, very

Fig. 4-14. New forage legume Galega in Hokkaido (Photograph by Dr. K. Okumura).

Fig. 4-15. Corn field in Tokachi distract (Photograph by Dr. K. Koinuma).

early maturing types (75 days) are cultivated. Seeds of many hybrid cultivars come from the USA and Europe. Sweet corn is also cultivated in Hokkaido.

3. Breeding program

Plant breeding is the intentional genetic manipulation of plant species in order to create desired phenotypes for specific purposes. Improvement of various agronomical characters such as yield, quality, and disease and insect resistance by breeding is essential for stable and high production.

Breeding programs on orchardgrass, meadow fescue, alfalfa, red clover, and white clover are now carried out at the National Agricultural Research Center for Hokkaido Region (NARCH). Breeding of timothy is done at the Hokkaido Pref. Kitami Agric. Exp. Station (timothy), and also by some private companies. Main breeding objectives for perennial forage crops are winter hardiness, yield, forage quality, persistency and disease resistance. Evaluation of plants/accessions introduced or collected from Hokkaido region and foreign countries is undertaken at experimental fields (Fig. 4-16), and superior genotypes with desired characteristics are selected. New breeding lines thus developed at the breeding stations are tested for local adaptation and specific characteristics such as suitability for grazing and cold tolerance etc., at several experimental sites throughout Hokkaido (Fig. 4-17). Based on the data from these evaluations, high performing breeding line(s) are registered as a recommended variety(ies) for general cultivation in Hokkaido.

(1) Perennial forage crops

Many forage crops are polyploids and obligate out-breeders. Conventional breeding of forage crops is mainly based on synthetic varieties developed through poly-crosses among superior selected genotypes (Fig 4-18).

1) Timothy

Recent breeding objectives of timothy are lodging resistance, mix-sowing ability with forage legumes, re-growth in summer and good seed production. Lodging results in bad forage quality. Lodging resistance is also essential for mechanical harvesting.

Fig. 4-16. Experimental field for selection of timothy. Hokkaido Pref. Kitami Agric. Exp. Station.

Fig. 4-17. Experimental field for local adaptability test of timothy. Hokkaido Pref. Konsen Agric. Exp. Station.

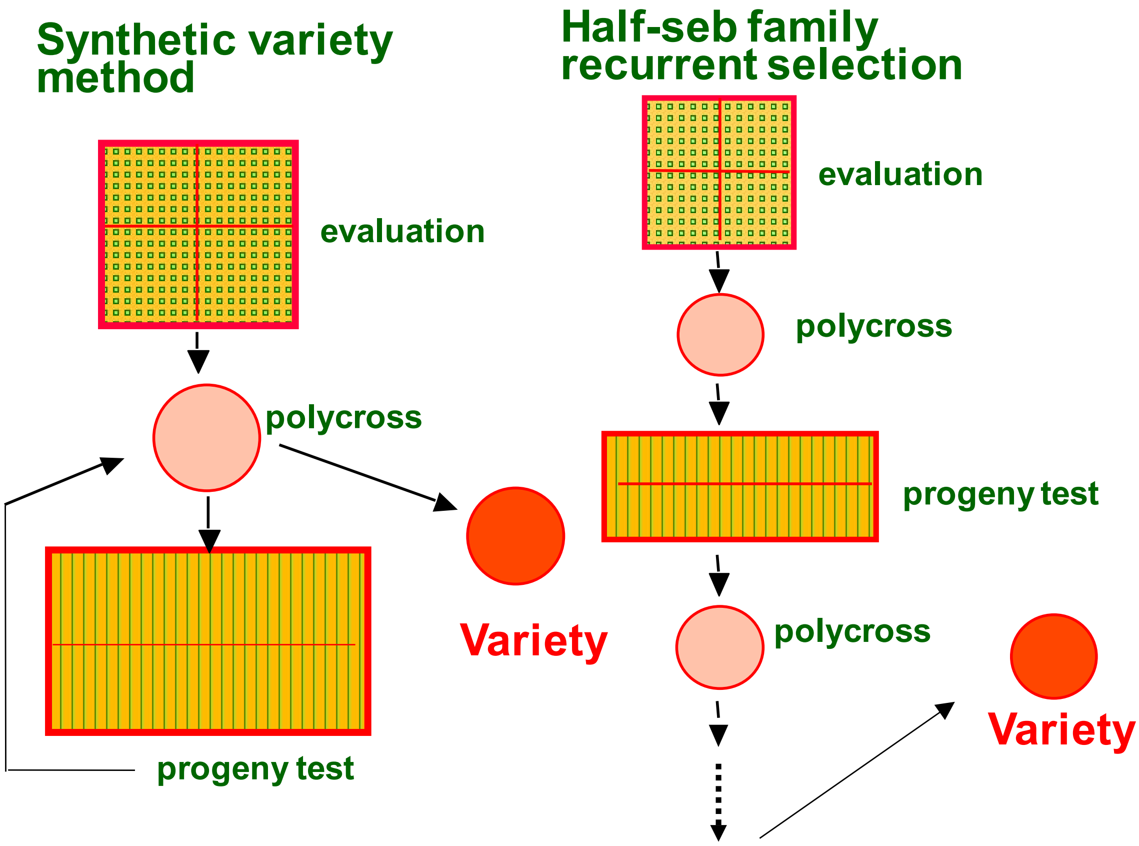


Fig 4-18 Breeding methods in perennial forage crops.

2) Orchardgrass

Water soluble carbohydrate (WSC) is an important trait for the nutritive value of forages because of its relation to palatability, digestibility and fermentation quality of silage. The WSC content and its composition are also correlated with freezing tolerance. The WSC content of orchardgrass is lower than that of other temperate grasses. Thus at NARCH the breeding program aims at increasing the content of WSC, and some promising breeding lines with high content of WSC have been developed. A new orchardgrass cultivar with high WSC content is likely to be released soon. There is generally a negative correlation between freezing tolerance and plant vigor in autumn (Fig. 4-19). Recently, a new cultivar 'Harunemidori' with both good winter hardiness and high production in autumn has been released. This cultivar showed a rapid increase in freezing tolerance in late autumn (Fig. 4-20). 'Harunemidori' is an ideal cultivar for Hokkaido region, which is located at mid latitude and has severe winter cold.

3) Perennial ryegrass

Recently, the Hokkaido Pref. Tenpoku Agri. Exp. Station has released a variety, 'Pokoro', which has moderate winter hardiness and high herbage production for grazing pasture. Figure 4-21 shows perennial ryegrass attacked by snow mould fungus, which is a major winter disease in Hokkaido. The new cultivar is resistant to snow mould and thus yields higher than susceptible ones.

4) Forage legumes

The breeding objectives of forage legume, white clover are winter hardiness and persistency. Red clover is improved for persistency, winter hardiness and compatibility for mix-cultivation with timothy. Breeding of alfalfa is aimed at improving persistency, yield, resistance to pepper spot and tolerance to trampling by heavy agricultural machinery. These legumes are pollinated by insects, mainly bees.

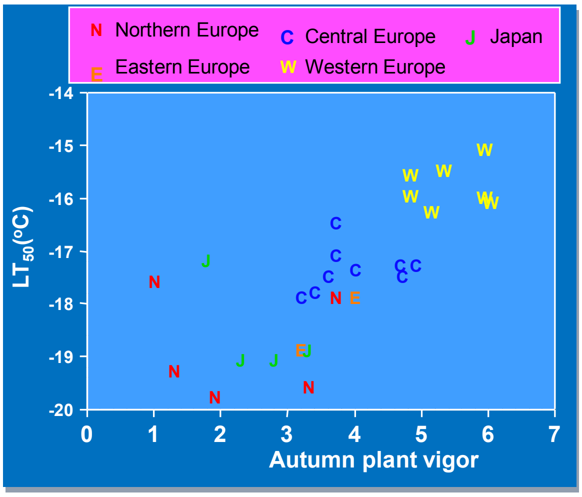


Fig. 4-19. Relationship between freezing tolerance (LT_{50}) and plant vigor in ochard grass populations during autumn (from Nakayama et al. 1997).

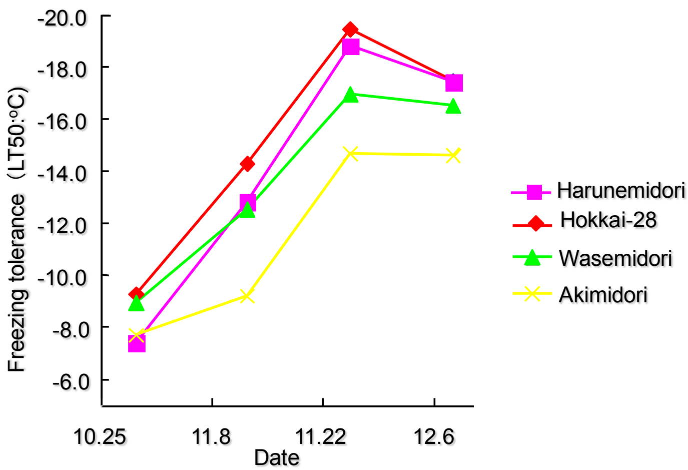


Fig. 4-20. Change of LT_{50} in four cultivars of orchardgrass during autumn

Fig. 4-21. Winter pathogen, snow mould disease in perennial ryegrass. Left two rows: resistant cultivar, right two rows: susceptible cultivar.

(2) Corn

All corn cultivars are hybrids. Hybrid is the first generation progeny from a cross involving inbred lines. The objectives of corn breeding in Hokkaido are improvement in growth at low temperature, yield, lodging resistance and forage quality. Hybrids have been developed from single crosses between high yielding inbreed lines of dent corn and northern flint having good growth at low temperature (Fig. 4-22).

4. Utilization of forage crops

(1) Grazing management

Grazing (Fig. 4-23) management involves manipulation of the soil-plant-animal complex to achieve the desired results. Grazing is not common in Japan including Hokkaido because it is not feasible to produce enough milk from limited lands. An intensive grazing system has been developed at NARCH combining short rotational grazing with silage production. Herbage production differs from season to season; from spring flush to summer slump. Utilization of sward for short rotational grazing and silage production in time of spring flush is reliable and efficient (Fig. 4-24). Such an intensive grazing system using 'Harusakae', a new winter-hardy meadow fescue cultivar has been established for eastern Hokkaido under a research project supported by the Ministry of Agriculture, Forestry and Fisheries (Fig. 4-25).

(2) Preservation of forage as hay and silage

Forage crops are harvested two or three times in a year, and stored for use as a consistent, reliable and predictable feed supply system for confinement feeding to dairy and beef animals. Common forms of storage are hay (usually with less 20% moisture) and silage preserved by anaerobic fermentation. Maturity stage at harvest is considered to be the primary factor affecting forage quality. Generally, forage quality declines with increase in growth stage of forage crops. Fig. 4-26 illustrates a typical relationship between quality and maturity stages based on cell wall components (fibrous constituents) and digestibility. The general trend is that digestibility declines with increase in maturity, while fibrous constituents increase. The best harvest time for good forage quality with

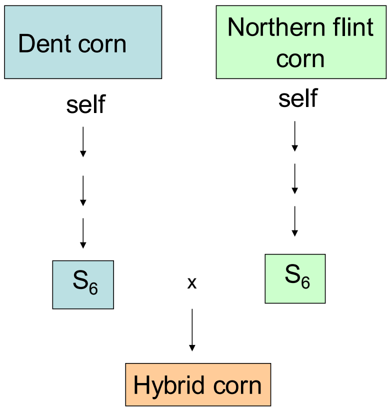
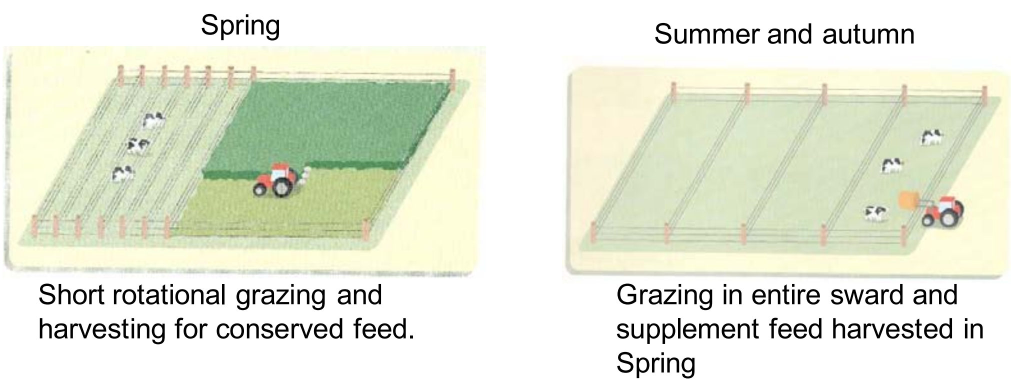


Fig. 4-22. Single cross hybrid corn seed production (Breeding program at NARCH).

Fig. 4-23. Grazing (Photograph by N. Sato).



(From NARCH)

Fig. 4-24. Intensive grazing system.

Fig. 4-25. Experiment on intensive grazing system using meadow fescue in Tokachi district (Photograph by T. Matsumura).

high herbage production is heading stage. In Hokkaido, relatively earlier harvest at booting to heading stage has been recommended for cultivation of timothy.

1) Hay harvest

Moisture content in fresh forage crops is often 75 to 85%. Thus a large amount of water must be removed to produce hay. Weather is one of the important factors for drying. First crop-cutting time in Hokkaido is the middle of June to early July. Unlike other parts of Japan, Hokkaido normally does not have rains in June-July and thus has relatively low humidity. Therefore, timothy is harvested in June-July to produce high quality of hay.

2) Silage production

Silage is forage preserved by anaerobic storage, usually under conditions that encourage fermentation for conversion of sugar to organic acids such as lactic, acetic and propionic acids. The lactic acid bacteria are mainly involved in fermentation. Silage system is widely used for preserving forage in Hokkaido. Corn is harvested for whole crop silage. Fig. 4-27 shows corn harvest and making of whole crop silage in Tokachi district. Silage production is easier than hay production because there is no requirement of several good weather days for drying. The production of chopped silage has been mechanized; so labor inputs are lower than for hay. Because of lower mechanical losses in silage production, harvest losses are lower than in hay production. Wrapped round bales (Fig. 4-28) and bunker silos (Fig. 4-29) are often seen in Hokkaido.

5. Status and future prospects

In a couple of past decades in Hokkaido as well as in other parts of Japan, number of cow and cattle per farm has increased and number of farmers has decreased. Thus dairy farming and beef production in Japan depend largely on imported feed (Table 4-2). Some mega-farms (annual production 1,000 t milk per farm), which use mainly imported feeds have appeared in Hokkaido recently. Due to this a large number of problems have arisen in animal production including environmental pollution by animal wastes and serious animal diseases such as foot and mouse disease and bovine spongiform encephalopathy (BSE). The self-sufficiency rate of animal feed has been decreasing. The fundamental

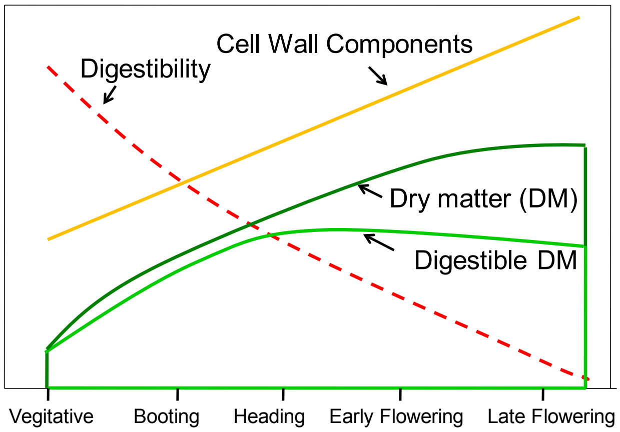


Fig. 4-26. Effect of maturity on forage quality in grasses.

Fig. 4-27. Harvest of corn to make whole crop silage in Tokachi district (Photographs by Dr. N. Fujita).

Fig. 4-28. Wrapped round bales for grass silage (Photograph by M. Takayama).

Fig. 4-29. Bunker silo for grass silage covered with polyethylene and used tires.

of dairy farming is nutrient cycling based on the involvement of the soil-plant-animal complex. Most of the nutrients contained in the forages and consumed by the animals are recycled to soil as urine and dung (Fig. 4-30). The dependence on concentrated imported feeds has caused too much accumulation of nutrients in soil leading to environmental pollution such as volatilization and nutrients runoff to rivers. During 2007-2008, the price of imported corn grains for animal feed had drastically increased. This was due to shortage in supply from USA as grains were used for ethanol production. Thus self-sufficiency in forage production is essential for secure and safe animal production. This requires developing new forage cultivars with higher productivity and quality. There is an urgent need to establish an efficient system for utilization of animal waste. Biogas systems with methane fermentation have been installed in some farms of Hokkaido (Fig. 4-31). Methane gas is used for fuel and electricity generation. Establishment of a sustainable grassland-farming system is essential in Hokkaido.

Table 4-2. Demand-supply of animal feed in Japan.
(TDN base unit: 1,000 t)

Demand				25,529
Supply	Domestic	Roughage		4,272
		Concentrate	Domestic materials	1,905
			Imported materials	4,076
			total	5,981
		Total		10,253
	Imported	Rouhhage		1,269
		Concentrate		14,007
		Total		15,276
	Roughage total			5,541
	Concentrate total			19,988
	Feed self-sufficiency rate			40.2 %
	Net domestic feed self-sufficiency rate			**24.2 %**

TDN: total digestible nutritions (From MAFF)

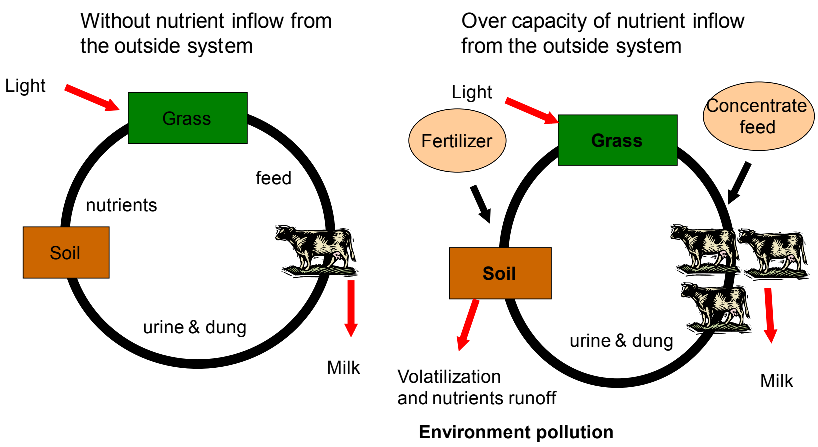


Fig. 4-30. Nutrient cycling systems in dairy farm.

Fig. 4-31. Biogas system with methane fermentation.

Livestock production

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Chapter 5

Livestock Production

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Hokkaido is a major area of livestock production in Japan. According to Statistics on Agriculture, Forestry and Fisheries (Table 5-1), in 2006, the livestock production of Hokkaido was of 502 billion yen, accounting for 18.6% of the total livestock output of Japan, and was the highest among Japan's 47 prefectures. Dairy farming holds a dominant position in Japan's livestock production.

There is a large area of grasslands in Hokkaido, accounting 72.7% of the national area of grasslands. In 2006, the number of dairy farmers was 8,590 and there were 859,100 dairy cattle, which meant 100 cows per farm. Dairy farms in Hokkaido are shipping 3,798,123 metric tons of milk (Table 5-2), that is, 46.7% of Japan's total milk production (Table 5-1).

1. Dairy

It is said that dairy farming in Hokkaido began with the milking of “Nanbu Cattle” in Hakodate city in 1857. In 1873, Mr. Edwin Dan, an agricultural expert from United States, arrived as an advisor with commissioner Capron. He taught the system of livestock production to Hokkaido's people for 9 years. He laid the foundation for dairy farming by introducing “Durham“ (Shorthorn) cows, which were used for both milk and beef in the United States.

In 1878, the Sapporo Agricultural College imported “Ayrshire” milking cows. In 1889, for the first time in Japan, the college imported “Holstein” cattle (3 females, “Shikishima”, “Sazanami” and “Chidori”; 2 males, “Akitsushima” and “Yamato”: as named in Japanese). Their descendants can be seen in the present barn of the Experimental Farm, Field Science Center for Northern Biosphere (FSC), Hokkaido University (Fig. 5-1). “Holstein” is now the major

Table 5-1. Hokkaido's share of grassland area and livestock production in Japan.

	Unit	Hokkaido (A)	Japan (B)	Share (A/B), %
Land Area				
Grasslands	1,000 ha	565	777	72.7
Gross Agricultural Output				
Gross Output		1,066	8,806	12.1
Livestock Output	billion yen	502	2,702	18.6
Milk		279	666	41.9
Number of Livestock raised				
Dairy Cattle		859	1,635	52.5
Beef Cattle		467	2,755	17.0
Pig	1,000 head	522	9,620	5.4
Layer		7,959	176,867	4.5
Race Horse		10	10	95.9
Quantity of Livestock Product				
Milk	1,000	3,798	8,134	46.7
Beef	metric ton	74	500	14.8

Statistics on Agriculture, Forestry and Fisheries (MAFF, 2006)

Table 5-2. Yearly changes in livestock production in Hokkaido. (Units: head, ton)

Year	Dairy Cattle		Beef Cattle		Pig		Layer	
	No.	Milk Production	No.	Dressed Carcass	No.	Dressed Carcass	No.	Chicken Egg
1965	317,690	663,546	13,690	7,711	163,390	18,793	3,839,000	34,480
1975	614,800	1,447,640	125,460	17,778	438,010	57,400	6,041,000	78,989
1985	807,800	2,603,483	245,000	57,330	604,000	87,095	7,633,000	92,194
1995	882,900	3,443,060	430,400	92,034	582,400	78,187	8,313,000	112,581
2000	866,900	3,645,698	413,500	74,528	546,100	72,222	8,237,000	110,781
2004	863,500	3,821,238	446,800	75,050	535,400	72,390	7,474,000	107,147
2005	857,500	3,861,101	447,700	74,111	-	70,615	-	105,738
2006	859,100	3,798,123	467,000	73,613	521,900	70,617	7,959,000	106,067

Statistics on Agriculture, Forestry and Fisheries (MAFF)

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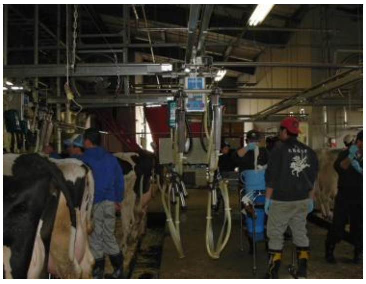

Fig. 5-1. Experimental Farm of Field Science Center for Northern Biosphere (FSC), Hokkaido University.

1. Dairy cattle barn. 2. Grazing of lactating dairy cows. 3. Milking of cows.

breed of milking cows in Japan (Fig. 5-2).

In 1960s, the westernization of the Japanese diet increased the demand for milk and dairy products. To cope with this, modernization and the expansion of dairy farms and improvement of grasslands were undertaken. Facilities equipped with modern machinery were set up.

However, as farm sizes expanded, high labor requirement in dairy farming had become a significant problem in Hokkaido (Fig. 5-3). To overcome this, a farm-helper association was set up in each region to allow farmers regular holidays and to prepare for accident and/or disease. However, certain problems as described below have been observed in the efficient utilization of the grassland ecosystem.

In Hokkaido, the number of dairy cattle has gradually increased over the past 30 years, while the area of grasslands has remained nearly constant (Fig. 5-4). The milk yield per cow per 305 days has markedly increased from 6,000 kg in the mid 1970s to the present 9,000 kg. Over the same period, the amount of concentrates fed has also greatly increased (Fig. 5-5). As a result, the self-sufficiency rate of feed (on a Total Digestible Nutrients [TDN] basis) in dairy farming has decreased from 75% in 1975 to 55% in 2004. Clearly the remarkable increase in milk production could not have been achieved in Hokkaido without the genetic improvement of Holstein cows as well as the heavy consumption of imported concentrates. The present situation has led to environmental pollution by extra feces and urine, which cannot be absorbed and utilized by plants.

The supply of safe milk can be sustained and achieved only by returning to the fundamentals of dairy farming, that is, by producing milk primarily through the soil-grass-animal interaction based on land use, without relying on the present concentrate based milk production system. Grazing is now being recognized as a sustainable production system in harmony with the environment. Grazing is a labor saving management system. The cows on pasture directly affect the soil-grass-animal interaction. The productivity grazing is generally regarded to be lower than forage harvesting. Sustainable grazing systems should aim not only to be harmony with the environment, but also to increase pasture productivity while maintaining sward characteristics.

Fig. 5-2. Holstein.

Fig. 5-3. Large-scale dairy farm “Mega farm” in Tokachi district in Hokkaido.

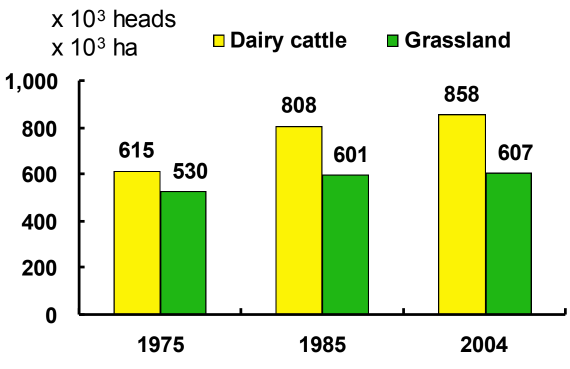

Fig. 5-4. Number of dairy cattle and area of grasslands (including forage-crop field) in Hokkaido.

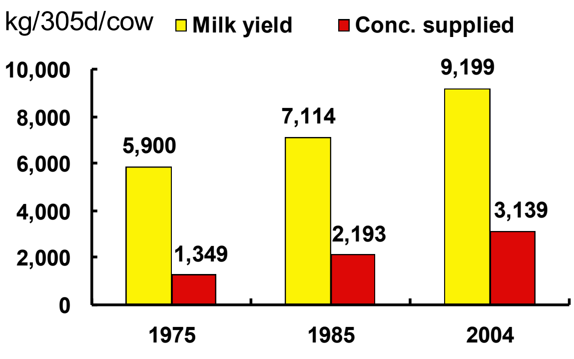

Fig. 5-5. Mean milk yield and concentrate supplied during the lactation of Holstein cows in Hokkaido.

Dairy farming is an activity based on the grassland ecosystem, in the same way as crop farming is based on the agro-ecosystem. As crop production is usually measured as the yield per unit area cultivated, the milk production should be expressed as the yield per unit area used for forage production, in addition to the yield per cow. In the case of grazing, milk production from pasture should be defined as milk yield per unit area of pasture. There have been many reports of milk production per unit area of pasture in United Kingdom and New Zealand, although only limited data are available in East Asia. However, we have almost completed compilation of such data from our researches of dairy farms in Hokkaido, and a series of grazing experiments were carried out in the Experimental Farm of FSC, Hokkaido University. Results of the studies will be discussed during the lecture.

2. Beef cattle

It is said that the raising of beef cattle was started in 1858, when “Nanbu Cattle” was introduced in Nanae town in the southwestern region of Hokkaido. “Japanese Brown Cattle” (Katsumoo-Washu) (Fig. 5-6) and “Japanese Shorthorn” (Nihon-Tankakushu) (Fig. 5-7) were also introduced to complement fishermen’s unstable incomes.

Since 1960s, with rapid economic growth the demand for beef in Japan has increased. The number of castrated male “Holsteins” as beef cattle increased the most in Hokkaido. In addition, during 1960s, new foreign breeds such as “Aberdeen-Angus” (Fig. 5-8) and “Hereford” (Fig. 5-9), which have a high ability of forage utilization, were imported and experimented with grazing and high-forage-based diets, especially in Hokkaido. The Shizunai Livestock Farm of FSC located in Hidaka district, 150 km to the southeast of Sapporo, has kept about 100 heads of “Hereford” till now. Experiments were conducted on comparison of the grass-fed-beef (lean meat) production system with grazing on the mountain-slope pasture in summer and high forage based diets including mainly corn silage in winter.

Since 1991, when the Japanese beef market was opened to foreign trade, the meat produced from Holstein and the foreign breeds lost competitiveness against the imported beef, owing to similar quality. At present, “Japanese Black

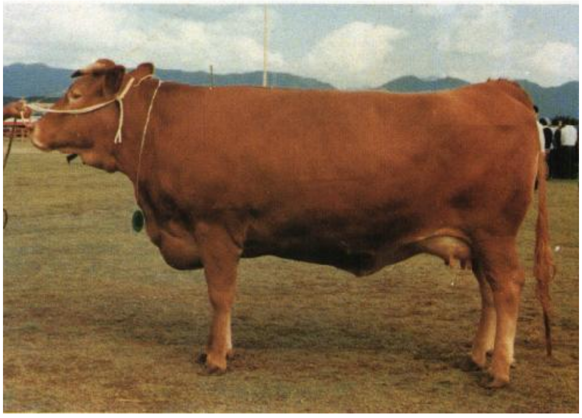

Fig. 5-6. Japanese Brown Cattle (Katsumoo-Washu).

Fig. 5-7. Japanese Shorthorn (Nihon-Tankakushu).

Fig. 5-8. Aberdeen-Angus.

Fig. 5-9. Herford.

Cattle” (Kuroge-Washu) (Fig. 5-10), which is raised and fattened by high grain based diets, is popular, producing high quality beef (with marbling) that competes with imported beef.

In 2006, the number of beef cattle farmers was 3,000 in Hokkaido. There were 467,000 heads of beef cattle and 73,613 metric tons of beef dressed carcasses were produced (Table 5-2), accounting for 17.0 % and 7.9 % of the total beef cattle raised and beef dressed carcasses produced in Japan, respectively (Table 5-1). Both the number of beef cattle raised and beef meat produced are the highest in Hokkaido among Japan’s 47 prefectures.

The strategies for cost reduction, the establishment of Hokkaido Brand Beef, and the expansion of markets will be important in order to prepare for international competition. Due to globally soaring grain prices the grass-fed-beef production system with grazing and high-forage-based diets must be recognized once again as a low cost production system, which is also a sustainable production system in harmony with the environment. Like milk production, a sustainable supply of safe beef can be achieved only by returning to the fundamentals of beef production, that is, by producing beef primarily through the soil-grass-animal interaction based on land use, without relying on the concentrate-based beef production system.

3. Pigs

In 2006, Hokkaido’s pig farms had 521,900 pigs, accounting for 5.4% of the national total (Table 5-1). These were distributed amongst 323 farmers, and produced 70,617 metric tons of pork dressed carcasses (Table 5-2).

Almost all pigs raised in Hokkaido are hybrids, in particular “three-way crossbreds” among “Landrace” (Fig. 5-11), “Large White” (Fig. 5-12) and “Duroc” (Fig. 5-13). Purebreeds of “Landrace” sows and “Duroc” boars can be seen at the Experimental Farm of FSC. The number of SPF (Specific Pathogen Free) pigs is increasing leading to production of safe and delicious pork.

4. Chickens

In 2006, the number of egg-laying hens was 7,959,000 in Hokkaido, accounting for 4.5% of the national total (Table 5-1). There were 93 poultry farms,

Fig. 5-10. Japanese Black Cattle (Kuroge-Washu).

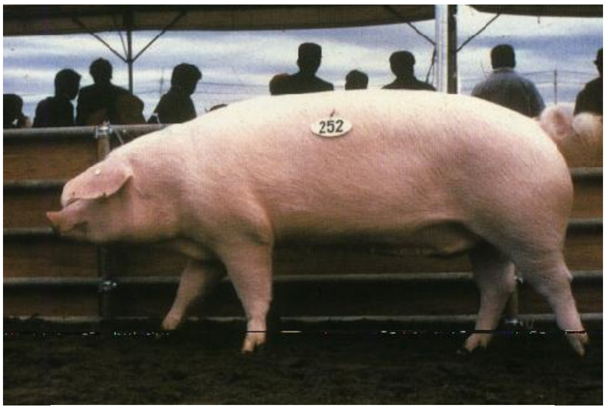

Fig. 5-11. Landrace.

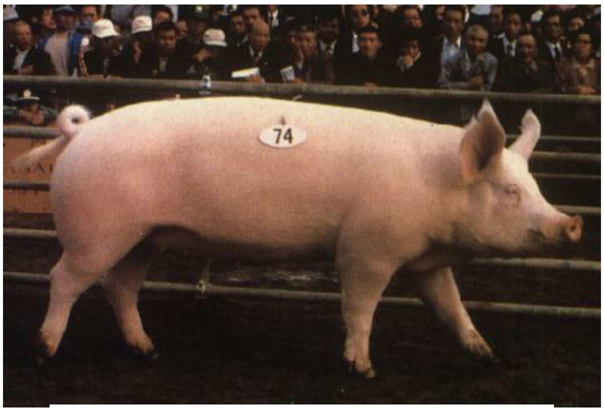

Fig. 5-12. Large White.

Fig. 5-13. Duroc.

egg production was 106,067 metric tons (Table 5-2). As the number of farmers has decreased, the scale of operation has expanded. Some breeds of egg-layers that can be seen at the Experimental Farm of FSC are “White Leghorn” (Fig. 5-14) and “Rhode Island Red” (Fig. 5-15).

Chicken meat production started in earnest in the late 1980s, when large companies moved to Hokkaido from other prefectures. The number of chickens for meat production was 30.51 million in 2005, with broiler chickens accounting 89% of the total chicken meat produced.

5. Sheep

In 2006, there were 6,452 sheep and 197 sheep farmers. The major breed of sheep for meat production is “Suffolk” (Fig. 5-16).

Almost all sheep meat consumed in Japan is now imported from Australia and New Zealand because of low prices. However, fresh and delicious lamb is becoming more popular in Hokkaido, and good quality wool is sought after for hand-made fabrics. Even though there are relatively few sheep in Hokkaido, they contribute significantly to tourism as popular sightseeing attractions.

6. Horses

Hokkaido is the center of racehorses with 9,838 “Thoroughbreds” (Fig. 5-17), accounting over 90% of the total horses in Japan. There were 1,109 horse farms in 2006. Due to the recession in Japan and increase of importation etc., the number of horses raised in Hokkaido has been declining since 1991.

There is also a native horse in Hokkaido, “Hokkaido-Washuba” (Fig. 5-18). It is dubbed “Dosanko”, which means a person born in Hokkaido. They are small in size and were introduced into Hokkaido from the main land of Japan about 200 or 300 years ago. They are kept outdoors all year round and used as packhorses. Their population was 1,468 in 2006, accounting about 75% of the total number of all Japanese native horses (8 breeds). Since 1950, the Shizunai Livestock Farm of FSC has about 80 horses of this breed, including about 30 mature mares, to maintain bloodline. Now, new usages of Hokkaido native horses are being considered, including endurance, trekking and horse riding by handicapped persons etc.

Fig. 5-14. White Leghorn.

Fig. 5-15. Rhode Island Red.

Fig. 5-16. Suffolk.

Fig. 5-17. Thoroughbred.

Fig. 5-18. Hokkaido Native Horse (Hokkaido-Washuba: "Dosanko").

Agricultural Machinery Technology

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Chapter 6

Agricultural Machinery Technology

Takashi Kataoka

1. Beginning of Mechanization in Agriculture in Hokkaido

(1) History of College Farm of Sapporo Agricultural College

Dr. William S. Clark, who was the president of Massachusetts Agricultural College in the U.S., was invited as vice-president of the Sapporo Agricultural College. He came with two other professors, Dr. Wheeler and Dr. Penharrow, in July 1876. The Sapporo Agricultural College was established on August 4, 1876.

On September 8, 1876, Dr. Clark requested the governor to build a well-equipped farm system. The ownership of the college farm was transferred from the governor to the college. The college had two different types of farms. The first farm was used for students' training in crop production, and the second was used as a model for dairy farming in Hokkaido. A new barn (Fig. 6-1) was got constructed by Dr. Clark as a model for dairy farming in Hokkaido.

Prof. Brooks was invited to the Sapporo Agricultural College in February, 1877 and Dr. Clark left Sapporo in April, 1877. Prof. Brooks suggested the construction of a corn barn (Fig. 6-2). He also imported many types of agricultural implements and tools for crops and cattle in May, 1877. He led both education and training on modern agriculture in Japan, and a considerable fruitful knowledge was generated from 1877 to 1879. The clock tower and the model barn of the Sapporo Agricultural College were built in 1877. Besides corn barn, other houses were also built and a new dairy farming system was practiced. Fig. 6-3 shows the tower silo used for making silage.

In 1969, the buildings of the second farm of the Sapporo Agricultural College were designated as "National Important Cultural Properties". In 2001, these were recognized as "Treasures of Hokkaido, and Properties for Future".

Fig. 6-1. The Model Barn.

Fig. 6-2. Corn Barn.

Fig. 6-3. Tower Silo.

Today, these are well known in Japan and considered as important heritages.

(2) The Model Barn

The Sapporo Agricultural College was the first to have the model barn. The building was originally named “The Delivery Room and the Stable”. However, Dr. Clark, the first vice-president of the college, named it “The Model Barn” because he thought this as the symbolic model of the modern agriculture in Hokkaido. Following Dr. Clark’s suggestion, Professor Wheeler, the second vice-president of the Sapporo Agricultural College, designed this building on the pattern of the barn of Massachusetts Agricultural College. Now, there are some tennis courts next to the university library. That is the place (depression) where “The Model Barn” was built in 1876. It was a two storied wooden building with a total floor area of 555 m^2 with gabled roofs. Later, the “The Model Barn” was transferred to the present place.

Such buildings in those days generally had a basement for the pig breeding, vegetable storage, excreta bin, space for making compost and so on. The first floor had sheds for cows and horses, cow breeding rooms, some stables for working horses, and delivery rooms. There was a long passage in the middle of the second floor, dividing it into two. At both sides of the passage were hay rooms. Since that passage was connected to the outer road, any horse wagon was able to come directly into the building from outside. That system relieved the workers from the hard task of carrying the hay up to the top floor. At the same time, it had only one way both for entry and exit toward slope so that no wagon could enter from the other side. The passage was provided with several holes on both sides. The holes were used by the workers to drop the hay to the first floor. There was also a garret in the building, which we might call “the third floor”. It was used as hayloft. The wooden rail for the hanging-lift was attached to the underside of its roof beam. There was an impressive fine sculpture of cow head on the outer wall of the model barn.

Currently, the model barn is utilized as a museum, and many old agricultural tools and machineries are on display in it. Fig. 6-4 shows one of the oldest tractors in Japan, which is a McCormic Deering Tractor imported in 1926. It had the engine of 4,650 cc, 24.8 PS (18.2 kW), and the weight of 2,282 kg.

Fig. 6-4. One of Oldest Tractor in Japan, McCormic Deering Tractor.

Fig. 6-5. Wheat Reaper (Re-build Specimen).

Mitsui Farm in Shari-town (near Shiretoko Peninsula), Hokkaido, was the first farm to import a tractor in Japan in 1915.

Fig. 6-5 shows the specimen of a wheat reaper imported by Mr. Capron for the Sapporo Agricultural College. He was an American who played pioneering important role in the history of Hokkaido in 1880s.

(3) Museums of Agricultural Machinery in Hokkaido

"Tuchi no Yakata" listed as "Treasures of Hokkaido, and Properties for Future" in 2004 is the Museum of Soils and Plows of the world, which is in Kami-furano town at the center of Hokkaido. Since this museum also displays more than 50 tractors of the world, it helps us to understand the history of the tractor's progress and soil tillage equipments. Fig. 6-6 shows the imported steam-engine tractor made in Canada, which is still able to move. Fig. 6-7 is of a four-wheel driven tractor of Benz named as a "Unimog". This tractor belonged to the Laboratory of Agricultural Machinery, Hokkaido University, and was in use for the students' experiments and laboratory until 20 years ago. We can see a model of corn cultivation (Fig. 6-8) on the wall of the museum.

Historical Village of Hokkaido (Hokkaido Kaitaku no Mura) located at Atsubetsu-ku in Sapporo has historical buildings concerning Agriculture. The breeding house for the silkworm, the European style barn for the sheep and the balloon frame barn for the cattle are some important structures at the museum, and these help to understand the modern agriculture system in Hokkaido. For more details please see the website http://www.kaitaku.or.jp/info/info.htm.

The museum 'Baron Archives' (Danshaku Shiryokan) in Hokuto city near Hakodate city presents the history and the equipments of potato cultivation used in Hokkaido (Fig. 6-9). Baron Ryokichi Kawata (1856~1951), an engineer of shipbuilding studied potato production at Oshima-tobetsu district of Kamiiso town (now Hokuto city). He imported big agricultural machines and equipments from United States of America and Europe. His farm was one of the biggest private farms in Hokkaido about 90 years ago. He had an improved variety of potato "Danshaku-imo", which is well known in Japan. Mr. Kawata also imported the oldest steam-engine car from USA, shown in Fig. 6-10.

Fig. 6-6.　A Steam–engine Tractor.

Fig. 6-7. Benz tractor, “Unimog”, used in Hokkaido University.

Fig. 6-8.　A Corn Growing Model.

Fig. 6-9 Danshaku Shiryokan.

2. Tractor

(1) History of Tractor Development

Steam was the first source of power for an engine. James Watt, a Scottish engineer, improved the primitive steam engine and its peripheral devices for commercialization in late 18^{th} century. A portable steam engine (Fig. 6-11) was used for thrashing in the U.S. in 1850s. That was not a self-mobile system. It was towed by animals. The first tractor with a steam engine was developed in the U.S. in 1858. The crawler type tractor with a steam engine was also developed in the U.S. in 1873. Cable plowing (Fig. 6-12) was a major work done by tractors at that time.

Since tractors were too heavy, plowing by mounting the plow directly on the tractor would have caused the machine to sink in the field. Therefore, two tractors placed at both ends of a field and with the plow swinging on a cable towed to both tractors were used for plowing the field by moving tractor from one end to the other. Tractor was also used as power source for thrashing.

In 1876, Otto first presented the theory of the four-cycle sparking ignition engine system in Germany. Fig. 6-13 shows one of the oldest gasoline engine tractors in the U.S.

R. Diesel, a German, invented in 1893 the compression ignition engine system known as the “Diesel Engine”. The diesel engine had the advantages of a high constant load and slow engine traveling speed as compared to the gasoline engine. Because of this, in the early 20^{th} century, power source of the tractor was rapidly changed from the gasoline engine to the diesel engine. However, at that time, the tractor was used for only drawing trailers or a power source for plowing and thrashing.

In 1922, R. Bosch invented the fuel pump system for the diesel engine in Germany. This innovative technology significantly improved the performance of diesel engines, resulting in higher power and a compact size. Fig. 6-14 shows a typical three-wheel tractor of early 1900s. The tractors with the PTO (Power Take Off) shaft for the power driven implements became popular as a general purpose tractor for power-tilling, seeding and weeding in addition to plowing and thrashing. The standards of PTO were established by the ASAE (The American Society for Agricultural Engineers) in 1927.

Fig. 6-10. The Oldest Steam-engine Car.

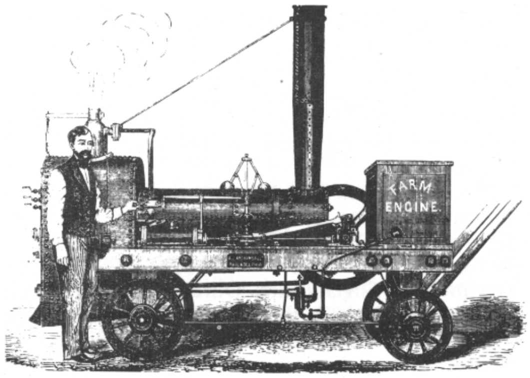


Fig. 6-11. Portable Steam Engine (1849).

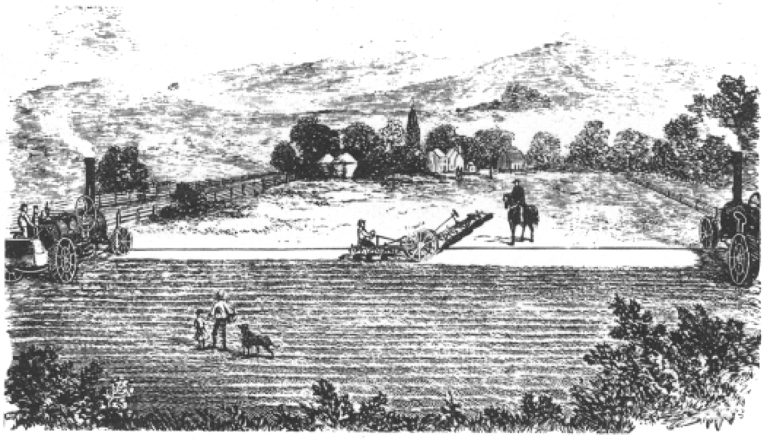
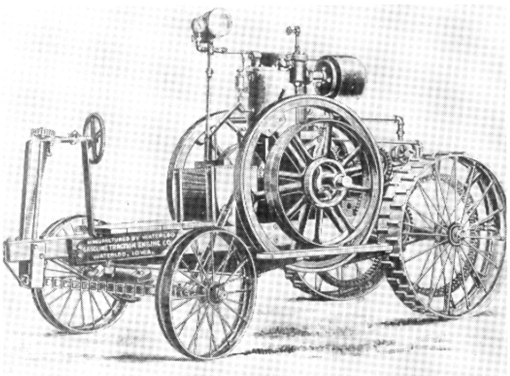
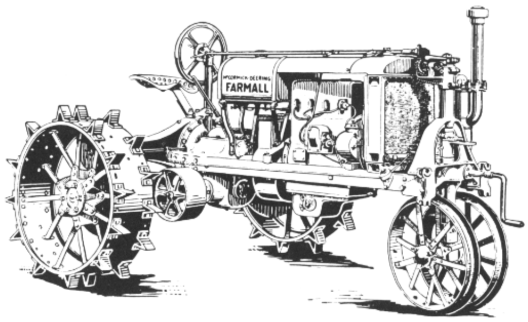


Fig. 6-12. Cable Plowing (English, 1859).



1892 Froelich

Fig. 6-13. Froelich Tractor (1892).



McCormick-Deering Farmall (2-plow)

Fig. 6-14. McCormic Deering Farmall Tractor (1924).

The other two important innovative technologies regarding tractor development were the installation of the rubber air tire (Fig. 6-15), and the hydraulic three-point hitching system. The rubber air tire was invented by J. Dunlop in 1877. The hydraulic three-point hitching system was invented by Massey Ferguson Company in Great Britain in 1935. Tractor became a multi purpose vehicle for drawing trailers as well as driving mounted type agricultural implements. The installation ratio of the rubber air tires in the market of tractors had been more than 95 % until 1940.

(2) Present Tractors

Fig. 6-16 is a typical style of the present tractor with four-wheel drive system (4WD). The turbo charged diesel engine is of 3,989 cc with a four-cylinder water cooled system, and 95 PS (69.9 kW)/2,200 rpm. The weight is 3,510 kg. The current biggest tractor in the world has 350 PS (257.3 kW).

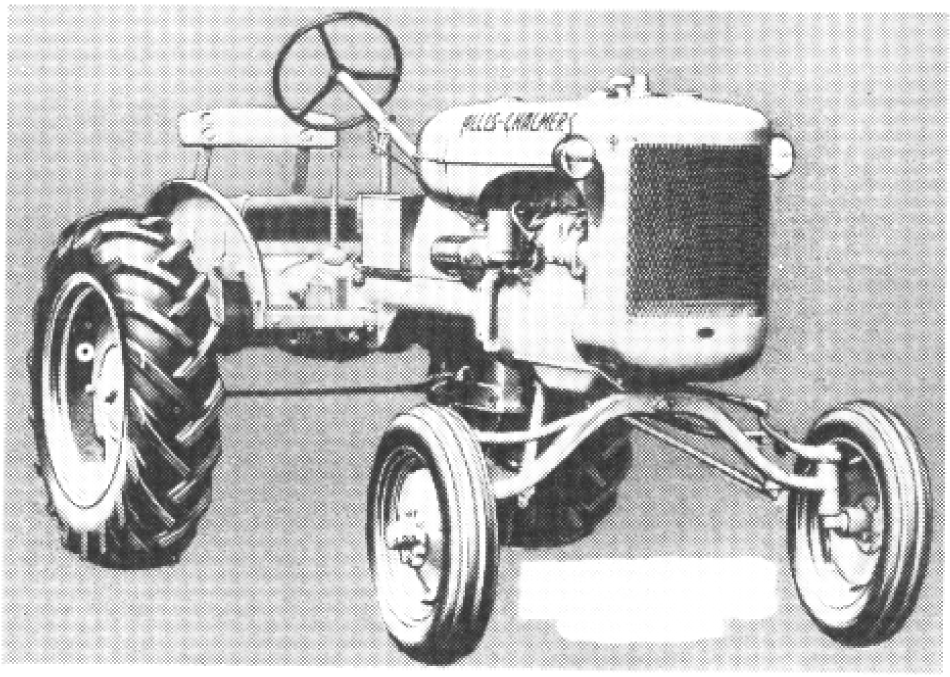
It is equipped with many electrical controls for operation. For example, the hydraulic steering control, the hydraulic three-point hitching control including draft-control for plowing and the level and depth controls for the rotary tiller, all-speed governor for the constant engine speed control, the shifting system for transmission, and the hydraulic assist pedals. All electronic functions are controlled by a computer. Furthermore, the automatic air-conditioning system and the radio are installed in the cabin to let the driver do his/her job comfortably. It thus differs from the classic tractor of McCormic Deering to a great extent (Fig. 6-4).

The tractor size is identified by the “horse power” of the engine. The required horse power is strongly related to the field size. The average tractor size is about 25 PS (18.4 kW) for paddy farming in Honshu island, whereas for the upland farm in Hokkaido, it is about 75 PS (55.1 kW). It is about 150 PS (110.3 kW) in the Great Plains of the U.S. The tractor size also vary for the different operations of crop cultivation.

3. Agricultural Machinery for different operations

(1) Tillage

The objectives of soil tillage are to prepare a suitable seedbed, to



Allis-Chalmers B

Fig. 6-15. Allis-Chakmers B Tractor (1938).

Fig. 6-16. Iseki Tractor T-950 (95 PS, 1997).

eliminate competition from weed growth, and to improve physical conditions of the soil. It may also involve removal, burial, or incorporation of manures and crop residues in the soil. The tillage operation may loosen, compact, or pulverize the soil. The best system of tillage is one which accomplishes these objectives with the least expenditure on labor and power (Martin et al., 1976).

In general, the tillage is divided into two stages, primary tillage and secondary tillage. The moldboard plow is a typical implement for the primary tillage (Fig. 6-17). The disk-plow is also used in relatively bigger farms as in the U.S. and Western Europe. The major function of the plow is turning the soil up-side down. The depth of the plow is generally 30 to 45 cm. Because the seeds of weeds go into the deep zone of the soil, soil turning reduces weed emergence. The residues of crops and the fertilizers on the surface are also buried into soil. The disk-plow is inferior to the moldboard plow in terms of its working ability. The former can perform smaller job than the latter. The latter can turn the soil more widely (Jacobs, et al., 1983). However, because the disks in the disk-plow rotate, it's required drafting force is smaller than that of the moldboard plow.

In secondary tillage, tines/blades driven harrow such as power harrow (Fig. 6-18) is used to make soft and flat seedbeds. The feature of this type is that it has the vertical drive shaft. The important function of the harrow is to pulverize the soil. The tilled clod size distribution should be decided according to the seed size, and this requires adjustment of the driving conditions of the implements, which include its working speed, its spinning speed and its cultivating speed. The pulverization and the clod size distribution affect the moisture content of the top soil for seed germination. The rotary tiller (Fig. 6-19) Which has the horizontal drive shaft is popular in Japan. It has been developed as tillage machine for the paddy fields of East Asia. The Japanese rotary tiller has C-shaped rotary blades called *Nata-zume*. The European type rotary tiller has L-shaped blades. The advantages of *Nata-zume* are lesser entwining of the straws on the blade, and reduced soil cutting resistance from firm soils such as the clayey soil of paddy fields. The performance of the rotary tillers made in Japan is quite different from tillers of other countries. The tillage depth of the rotary tiller is about 15 cm. It tills only the topsoil.

Fig. 6-17. Two-furrow Moldboard Plow of Reversible Type (Sugano-Noki, TROY1921DC).

Fig. 6-18. Power Harrow

Fig. 6-19. Rotary Tiller (Breviglievi, PRONTO-260).

In Hokkaido, plowing is done in late autumn, while rotary tillers or the power harrows are used for making seedbed of fine soil in spring. Since snow melting on the ground surface generally starts in the middle of April, farmers do not have enough time for both primary and secondary tillage before seeding. Two to three weeks are required for tillage.

(2) Sowing Implements

The general seeding mechanism operates as follow: (i) the double disk openers make the furrow, (ii) the seed is placed, (iii) the soil covering device close the furrow, and (iv) the press wheel compacts the surface soil. The seeder with fertilizer applicator (Fig. 6-20) is popular for sowing beans, corn and sugar beet. The combination of implements saves time. The seeder releases seeds using the vacuum aeration mechanism. It ensures good seeding keeping constant distance between seeds, and proper seeding depth. Fertilizer applicator is attached to most of the seeders and seeding implements. The variable rate control system for dusting or spraying fertilizers has been developed.

The drill is used for sowing of wheat, barley and grass, and planter for transplanting potatoes and nursery. Special transplanters with unique mechanisms are available for transplanting nurseries of sugar beet, carrots, onions and other vegetables. This advanced technology promotes sustainable and environment friendly agriculture.

(3) Weed, Insect and Disease Control Implements

Fig. 6-21 shows a sprayer attached to a utility vehicle having 14.5 PS (10.7 kW), four-wheel drive and four-wheel steering system (4WS). It is possible to attach a rotary weeding system to this vehicle, and this can be used for both upland and paddy fields because of its high ground clearance. It is used for spraying chemicals against weeds, insects and diseases. The swirl nozzle is commonly used to produce minute particles of spray.

The tine-type weeding machine is used for mechanical weeding. Mechanical weeding reduces the use of chemicals, and thus promotes the production of organic and safer agricultural products. The weeding machine

Fig. 6-20. Air Seeder with Fertilizer for Four-rows (Tabata, TJEVS-4LR).

Fig. 6-21. Utility Vehicle (Sprayer Version, Iseki JK-14).

(Fig. 6-22) has special rotating tines for weeding between rows and also between plants in a row. However, it requires high operational skills, and weeding needs to be done every week. Mechanical weeding system has lower working speed and weed removal performance.

(4) Harvester

There are different types of harvesters for various crops. Fig. 6-23 shows self-propelled combine harvester for wheat, beans, corn and other grain crops. The combine cuts the crop, feeds the crop to the thrashing cylinder, thrashes the seeds/grains from the seed head, separates the seeds/grains from the straw, cleans the seeds/grains, and handles the clean seeds/grains until these are loaded into a truck or trailer for transportation (Jacobs, et al., 1983). The word “combine” means the combination of the cutting and thrashing devices. The cutting head of the cutter and the pickup reel need to be replaced for different crops. The standard harvesting width is about 5 m. The Berry Company in the U.S. built the first self-propelled combine harvester with the straw-burning steam engine in 1866.

Fig. 6-24 is of a potato harvester. The blade of the harvester digs the potato tubers, and the tubers and soil are separated through several ladder conveyers to a storage tank. The workers on the harvester sort good tubers from green and damaged ones, and clods.

Since every crop requires different harvesting mechanism, farmers prepare harvesters for the various crops they cultivate, although a harvester is used only for one to two weeks in a year. Many types of harvesters have been developed, for example, for sugar beet, radish, lettuce, onion, cabbage, tomato, carrot etc. (Fig. 6-25).

(5) Forage cultivation

1) Hay production

Previously, cube bale was used in haymaking. Now, roll bale is used. The roll bale is better than cube bale because the harvesting speed of the harvester can be increased. Since roll bale is larger than a cube bale, the number of bales is lower. Transportation and handling operations are reduced

Fig. 6-22. Weeding Machine (Nichinoki-Seiko, NAK-5).

Fig. 6-23. Combine Harvester (New Holland, CS-540).

Fig. 6-24. Potato Harvester (Toyo-noki).

thereby saving time and labor (Culpin, 1975).

The hay harvesting involves cutting the grass using a mower (Fig. 6-26), turning it over for thorough drying using a gyro-type hay tedder (Fig. 6-27), making the windrows using a rake and making the roll bale using a roll baler (Fig. 6-28).

2) Silage production

Silage is a high protein feed produced from grasses and crops for the livestock. Grass silage is produced by wrapping roll bales in plastic films using wrapping machine. Fig. 6-29 shows the roll baler with the wrapping machine. This combined machine system has become popular because it saves time and cost. The roll bales wrapped with plastic films start fermenting and result in grass silages due to the action of lactic acid. The materials are covered with the plastic sheet to avoid aeration for production of good amount of lactic acid by fermentation. This methodology is preferred than the sealed tower silo method because it can be adapted to variable quantities of grasses and crops, and also involves less work for loading and unloading operations.

Corn for silage is harvested by the forage harvester, shown in Fig. 6-30. The forage harvester chops both stalk and leaves of the corn. The wagon track or the wagon towed by a tractor should run in parallel to the harvester to temporarily store the harvested material before the harvested corns are put into the bunker silo. The bunker silo is easier to use and maintain than tower silo.

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Fig. 6-25. Carrot Harvester (Kubota).

Fig. 6-26. Mower.

Fig. 6-27. Gyro-Tedder.

Fig. 6-28. Roll Baler.

Fig. 6-29. Roll Baler with Rapping Machine System.

Fig. 6-30. Forage Harvester Mounted on Tractor.

Agricultural Economy

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Chapter 7

Agricultural Economy

Yasutaka Yamamoto

The main objectives of this chapter are to contribute to a better understanding of Hokkaido's agriculture sector and the role it plays in the economy.

1. Food self-sufficiency ratio and producer support in Japan

(1) Food self-sufficiency ratio in Japan

Japan's food self-sufficiency ratio is the lowest among the major advanced countries (Fig. 7-1). Japan's food self-sufficiency ratio on a calorie basis has decreased from 60% in 1970 to 40% in 2000. This reduction was due to the tendency of domestic production to shift to relatively higher value added agricultural products such as vegetables and livestock products (MAFF, 2007a). The changes in dietary habit and increased imports of agricultural products have also caused a decline in the food self-sufficiency ratio.

(2) The level of producer support in Japan

The Japanese government seems reluctant to reduce Japan's agricultural trade barriers because Japan has a comparative disadvantage in agricultural production compared to relatively land-abundant developed countries such as the United States and Australia, or relatively labor-abundant developing countries such as China (Yamamoto, Sawauchi and Masuda, 2007). Therefore, Japan has been using tariff and non-tariff trade barriers in order to increase domestic producer prices of agricultural products and increase domestic agricultural production. Increased producer prices have led to more intensive agricultural systems in Japan.

Table 7-1 shows that high tariffs remain on farm and food-sector

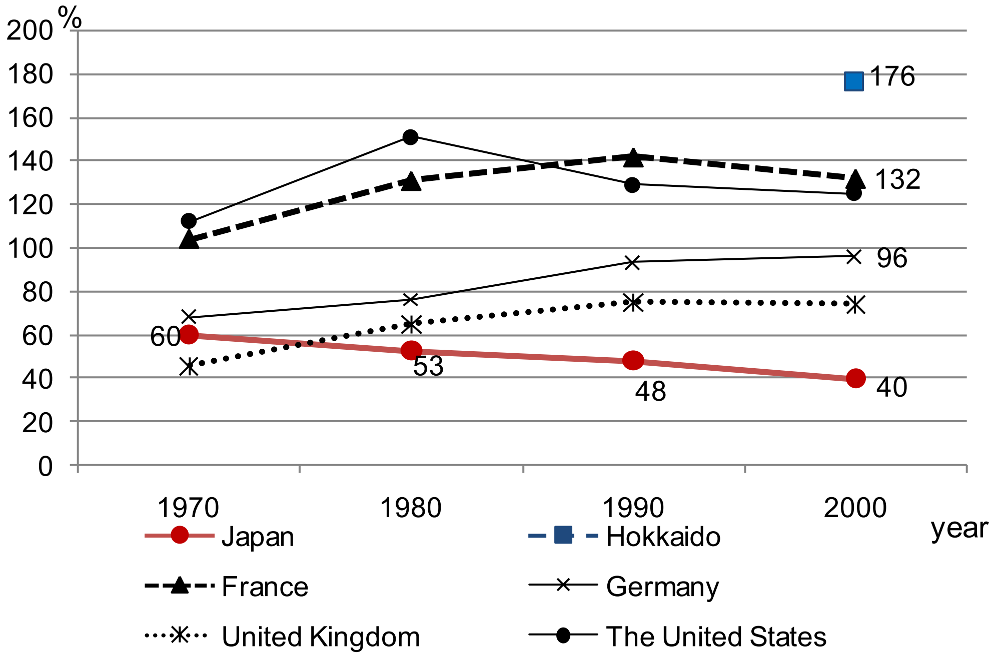

Fig. 7-1. Food self-sufficiency ratios on a calorie basis

Source: MAFF, Website (http://www.maff.go.jp/j/zyukyu/zikyu_ritu/012.html, http://www.maff.go.jp/j/zyukyu/zikyu_ritu/013.html, http://www.maff.go.jp/j/zyukyu/zikyu_ritu/zikyu_10.html).

Table 7-1. Ad Valorem tariffs of different commodities on bilateral basis (1997)

Unit:%

Commodity	Japanese tariffs on imports from Korea	Korean tariffs on imports from Japan
Rice	409	5
Wheat	249	3
Cerial grains	20	304
Other crops	38	74
Raw milk	0	0
Cattle & sheep	149	31
Other livestock	5	10
Rum meat	36	75
Other meat	58	22
Dairy products	287	26
Other food	38	45
Resource products	7	10
Manufacturing products	2	8
Services	0	0

Source: GTAP Database Version 5.4.

commodities in Japan (Yamamoto, Sawauchi and Masuda, 2007). The highest Japanese tariffs on imports from Korea are levied on rice (409%). Commodities whose tariffs are higher than 100% in Japan are rice, wheat, cattle & sheep and dairy products.

The percentage Producer Support Estimate (PSE) is the key indicator used to measure support to agricultural producers (OECD, 2008a). It expresses the estimated monetary value of policy transfers from consumers and taxpayers to producers as a percentage of gross farm receipts. The percentage PSE is suited to analyze changes in the level of support in the OECD area across time, as well as the levels of support across individual OECD countries.

In the OECD countries, support to producers, as measured by the percentage PSE, was 29% in 2004-06, implying that agricultural support increased farmers' gross receipts in OECD countries by more than one quarter (Fig. 7-2). In Japan, PSE has declined from 64% in 1986-88 to 55% in 2004-06, but almost twice the OECD average. There continued to be a considerable diversity in the level and composition of support among OECD countries. This reflects in part the wide variations in farm structures, natural environments, socio-economic conditions and trade positions (OECD, 2008a). In 2004-06, Australia and the United States had percentage PSE of 20% or below, while Japan and the European Union had support levels that were 30% or above.

2. Hokkaido's agriculture in Japan

(1) Agriculture's share of Economy

While Hokkaido's agriculture has played an important role in Hokkaido's regional economy, the size of agriculture has declined relative to the rest of the economy. Total economic output in Hokkaido has grown faster than its agricultural output, leading to a decline in agriculture's share over time.

Gross value added for agriculture, forestry and fisheries as a percentage of total Gross Prefectural Product for Hokkaido have declined from 7.5% in 1980 to 3.6% in 2005 (Fig. 7-3). Gross value added for agriculture, forestry and fisheries as percentage of total Gross Domestic Product for Japan has declined from 3.8% in 1980 to 1.5% in 2005. The trends of relative decline in agriculture's

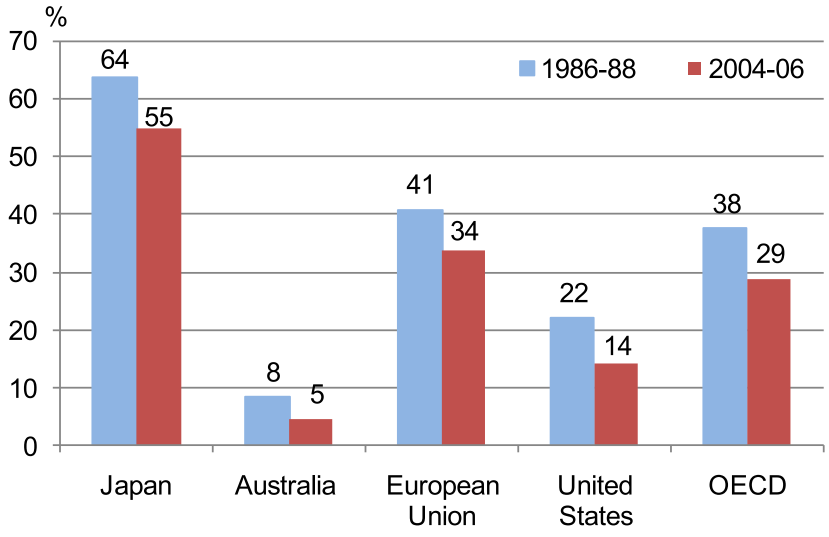

Fig. 7-2. Producer support estimates by countries

Source: OECD, *PSE/CSE database.*

Note: Data show the percentage share of Producer Support Estimates in GDP.

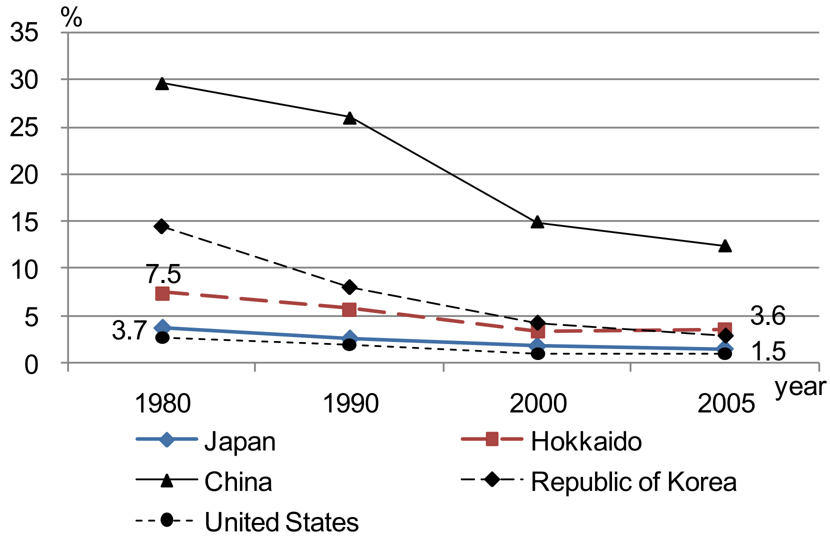

Fig. 7-3. Agricultural share of economy

Source: United Nations Statistics Division, *National Accounts Main Aggregates Database*. Economic and Social Research Institute Cabinet Office, *Annual Report on National Accounts and Annual Report on Prefectural Accounts*.

Note: Each value shows agricultural share of Gross Domestic Product in Japan, China, Republic of Korea, and the United States, and agricultural share of Gross Prefectural Product in Hokkaido.

share of economy are also found in other countries such as China, Republic of Korea and the United States.

(2) Contributions of Hokkaido to Japan's agriculture

While the trends of relative decline in agriculture's share of economy are found in Hokkaido, Hokkaido has played the most important role in Japan's agriculture.

Hokkaido is called 'Japan's biggest food supplier' for products such as wheat, soybeans, adzuki beans, sugar beet, corn, carrot, potatoes, onion, pumpkin, milk, beef, and racehorse. Average size of Hokkaido's farm household is the biggest in 47 prefectures of Japan mainly due to relatively abundant land resources compared with the rest of Japan.

An examination of the relative contributions and characteristics of Hokkaido's agriculture to Japan reveals that (Table 7-2):

-about one quarter of Japan's cultivated land and more than 80% of Japan's grasslands exist in Hokkaido;

-average cultivated land per farm in Hokkaido is more than ten times of the average cultivated land per farm in Japan;

-around 10% of agricultural gross output is produced in Hokkaido;

-Hokkaido produces more than 40% of Japan's raw milk, more than 60% of Japan's wheat and potatoes, and more than 80% of Japan's adzuki beans and sugar beet; and

-around half of Japan's dairy cattle exist in Hokkaido.

3. Farms in Hokkaido

(1) Number of farms

The number of commercial farm households[1)] in Hokkaido declined from 95 thousand in 1990 to 52 thousand in 2005 (Table 7-3). The number of commercial

Table 7-2. Comparisons between agriculture in Hokkaido and Japan

Content	Unit	Hokkaido A	Japan B	A/B	Sources: Year of Survey	Sources: Reference
Land area						
Cultivated land	1,000 ha	1,166	4,671	25.0%	2006	MAFF
Paddy field	1,000 ha	227	2,543	8.9%	2006	
Upland field	1,000 ha	939	2,128	44.1%	2006	
Grasslands	1,000 ha	523	627	83.4%	2006	
Cultivated land per farm	ha	19.8	1.3	1523.1%	2005	
Income						
National (prefectural) income	billion yen	14,308	361,013	4.0%	2004	Economic and Social Research Institute , Hokkaido
Agricultural income	billion yen	397	3,263	12.2%	2005	MAFF
Gross agricultural output						
Gross output (A)=(B)+(C)	billion yen	1,066	8,806	12.1%	2005	MAFF
Crop output (B)	billion yen	564	6,037	9.3%	2005	
Livestock output (C)	billion yen	502	2,702	18.6%	2005	
Quantity of agricultural production						
Rice	1,000 t	644	8,546	7.5%	2006	MAFF
Wheat	1,000 t	514	837	61.4%	2006	
Potato	1,000 t	2,008	2,598	77.3%	2006	
Soy bean	1,000 t	70	231	30.3%	2006	
Azuki bean	1,000 t	56	63	88.9%	2006	
Sugar beet	1,000 t	3,923	3,923	100.0%	2006	
Raw milk	1,000 t	3,798	8,134	46.7%	2006	
Beef	1,000 t	74	500	14.8%	2005	
Number of livestock raised						
Dairy cattle	1,000 head	856	1,635	52.4%	2005	MAFF
Beef cattle	1,000 head	467	2,755	17.0%	2005	
Pig	1,000 head	522	9,620	5.4%	2005	
Layer	1,000 head	7,787	176,955	4.4%	2005	

Source: Hokkaido prefectural government, *Agriculture in Hokkaido, Japan 2007*.

farm households in Japan declined from 3,835 thousand in 1990 to 1,963 thousand in 2005 (Table 7-4). The number of commercial farm households in Japan and Hokkaido declined by about 50% between 1990 and 2005.

In 2005, about half (52%) of Hokkaido's commercial farm households engaged in full-time farming. More than three quarters (77%) of Japan's commercial farm households engaged in part-time farming.

(2) Income of farm households

In Japan, until 1998 the key policy statements described the main objective of agricultural policy as "to enable farmers through increased farm income to enjoy equal standards of living with workers in other industries" (OECD, 2003).

Fig. 7-4 illustrates total income per farm household in Hokkaido and the rest of Japan. In 2005, total income per farm household in Hokkaido (6,551 thousand yen) was about 1.3 times larger than in the rest of Japan (4,971 thousand yen). Agricultural income per household in Hokkaido (5,150 thousand yen) was about 4.7 times larger than in the rest of Japan (1,101 thousand yen). However, non-agricultural income in the rest of Japan was larger than in Hokkaido.

Hokkaido was developed by immigrants from other parts of Japan after the Meiji Restoration. It has maintained its proportion of full-time farm households because the decline in the number of farm households has led to an increase in average farm size (Tama and Carpenter, 2007). The economic theory says that farm households that can support themselves on agricultural income alone will remain and others will leave farming; it has worked in the case of Hokkaido. This theory, however, has not held true for others parts of Japan, where small-scale farming has been maintained by compensating for income shortfalls from farming with off-farm employment by household members.

(3) Size of farms

Fig. 7-5 and Fig. 7-6 show the shares of number of rice farm households by size of cultivated land in Hokkaido and in the rest of Japan. The size of rice farm households in Hokkaido is much larger than in the rest of Japan. In 2005, the

Table 7-3. Number of farm households classified by full-time and part-time in Hokkaido

Unit: thou. household, %

Year	Total	Full-time farm household		Part-time farm household	
	a=b+c	b	b/a*100	c	c/a*100
1990	95	43	45%	53	55%
2000	63	29	46%	34	54%
2005	52	27	52%	25	48%
2005/1990	0.54	0.64	-	0.47	-

Source: MAFF, *Census of Agriculture and Forestry*.

Table 7-4. Number of farm households classified by full-time and part-time in Japan

Unit: thou. household, %

Year	Total	Full-time farm household		Part-time farm household	
	a=b+c	b	b/a*100	c	c/a*100
1990	3,835	592	15%	3,243	85%
2000	2,337	426	18%	1,911	82%
2005	1,963	443	23%	1,520	77%
2005/1990	0.51	0.75	-	0.47	-

Source: MAFF, *Census of Agriculture and Forestry*.

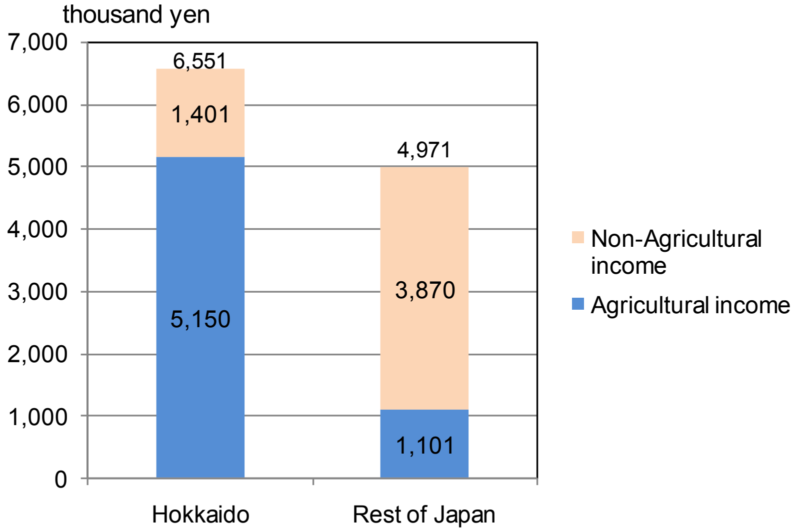

Fig. 7-4. Total income of farm household per farm (2005)

Source: MAFF, *Report of Statistical Survey on Farm Management and Economy (Statistics on Type of Management)*.

Note: Non-agricultural income = non-agricultural income + income of relational agriculture + annuity, presents, gifts, etc.

share of number of rice farm households that cultivated more than 10 ha was 44% in Hokkaido. In the rest of Japan, the share of rice farm households that cultivated more than 10 ha was less than 1%. In 2005, the share of number of rice farm households that cultivate less than 1 ha was 52% in the rest of Japan.

Fig. 7-7 and Fig. 7-8 show the shares of number of the dairy farm households by herd size in Hokkaido and in the rest of Japan. The size of dairy farm households in Hokkaido is much larger than in the rest of Japan. In 2005, the share of number of dairy farm households that raised 50-99 milking cows was about half (47%) in Hokkaido. In the rest of Japan, the share of dairy farm households that raised 50-99 milking cows was only 12%.

(4) Costs of production

Fig. 7-9 and Fig. 7-10 show the production costs per 60 kg of brown rice and per 100 kg of raw milk in Japan and Hokkaido. Costs of rice as well as raw milk production are lower in Hokkaido than in Japan since the size of farms in Hokkaido is larger than in Japan. As per famous economic law 'economies of scale', larger is the size of farms, lower is the production cost per agricultural output.

4. Multifunctionality of agriculture

The concept of "multifunctionality of agriculture" recognizes important potential benefits of agriculture in addition to the production of food, which is essential for human living. Agriculture and rural areas in Hokkaido besides producing agricultural products are playing a number of important roles including preservation of the natural environment and biodiversity, development of favorable landscapes, provision of recreational and educational opportunities to urban people, etc. Such benefits from multifunctionality of Hokkaido's agriculture was estimated at around five hundred billion yen per year, which is about half of the gross agricultural output value in Hokkaido (Demura, Sato and Iwamoto, 1999).

There is growing concern about fulfillment of the multifunctionality of agriculture due to stagnation of agricultural production and the decline in

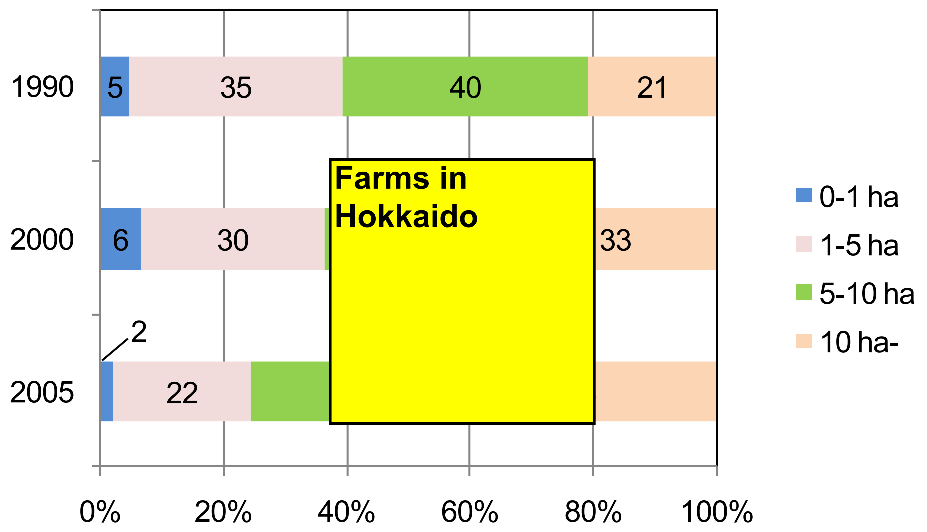

Fig. 7-5. Share of number of rice farm households by size of cultivated land in Hokkaido

Source: MAFF, *Census of Agriculture and Forestry*.

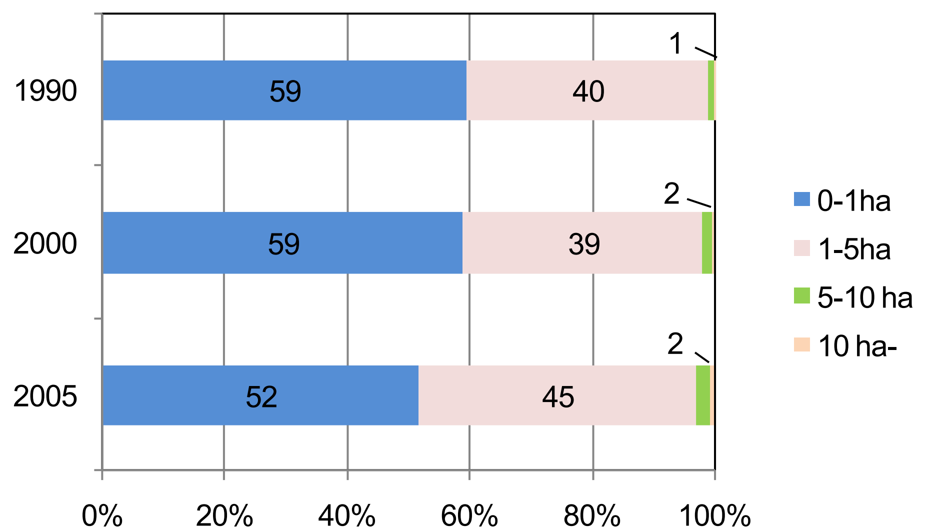

Fig. 7-6. Share of number of rice farm households by size of cultivated land in rest of Japan

Source: MAFF, *Census of Agriculture and Forestry*.

community functions (MAFF, 2007a). More efforts should be directed to further promote the understanding of the multifunctionality of agriculture.

Notes

1) The term of “farm household” used here refers to a household that operates farming with 10 ares and more of cultivated land on the survey date or a household whose agricultural product sales amount to a specific value (e.g. 500,000 yen in 2005) and over in a year prior to the survey date, even with its cultivated land being below 10 acres (MAFF, 2007b). Since 1990 Census, the “farm household” is further divided in two categories: “commercial farm household”, which is a farming household mainly producing agricultural products for sales, and “noncommercial farm household”, which is a farming household mainly producing agricultural products such as rice for its own use (MAFF, 2007b).

The “full time farm household” applied in the statistics on number of commercial farm households is defined as a farm household, which has no household member engaged in other jobs than farming (MAFF, 2007b). The “part-time farm household” is defined as a farming household, which has one or more household members engaged in other jobs than farming (MAFF, 2007b).

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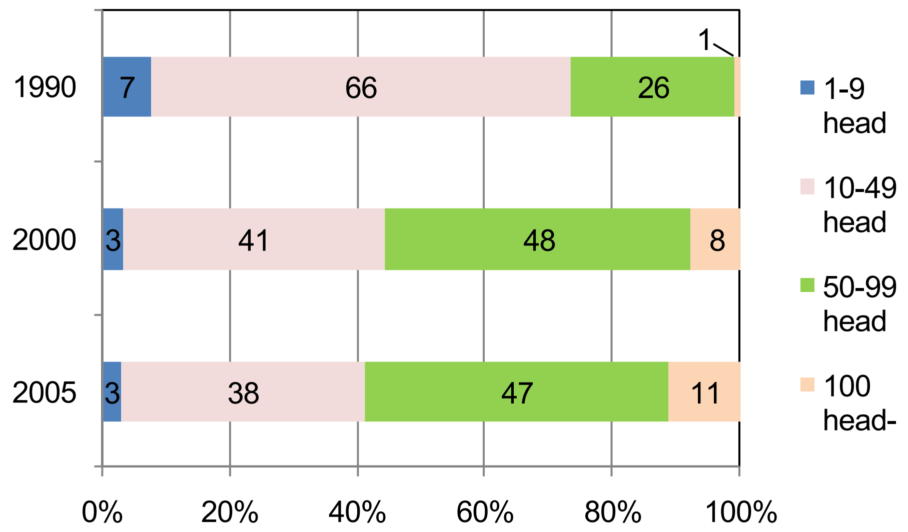

Fig. 7-7. Share of number of dairy farm households by herd size in Hokkaido
Source: MAFF, *Census of Agriculture and Forestry*.

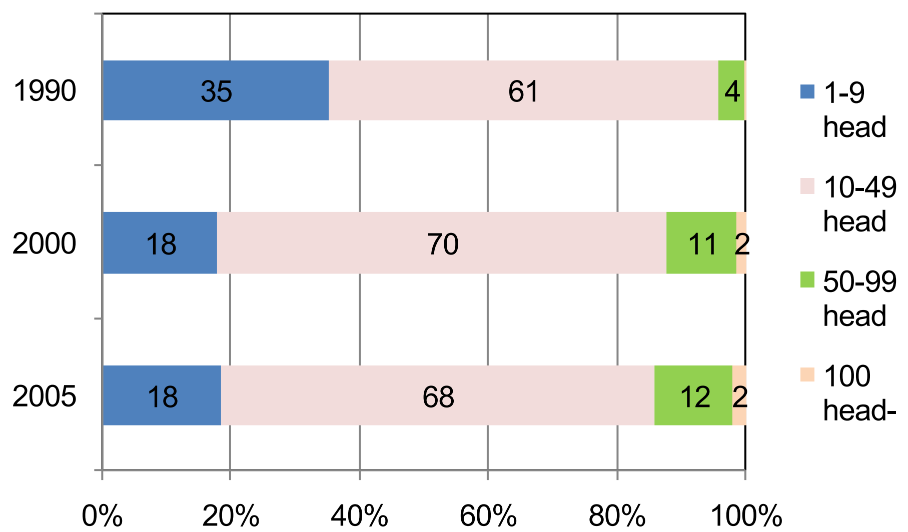

Fig. 7-8. Share of number of dairy farm households by herd size in the rest of Japan
Source: MAFF, *Census of Agriculture and Forestry*.

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Acknowledgement
The author thanks Dr. Daisuke Sawauchi for invaluable assistance in collecting and processing data and constructive comments on earlier drafts.

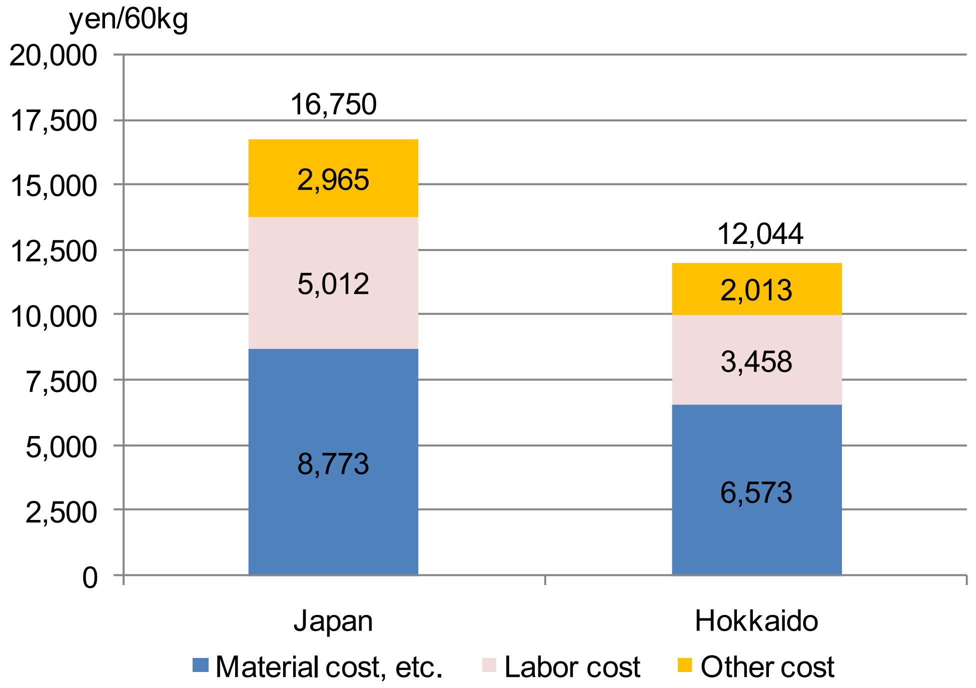

Fig. 7-9. Production cost of rice (2005)

Source: MAFF, *Report of Statistical Survey on Farm Management and Economy (Production Cost of Rice Wheat and Barley)*.

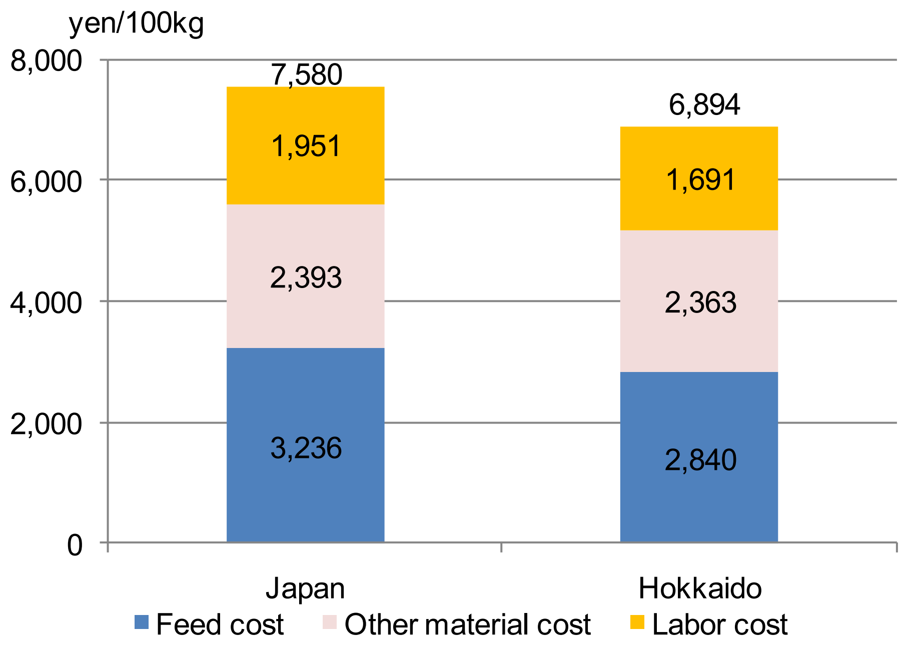

Fig. 7-10. Production cost of raw milk (2006)

Source: MAFF, *Report of Statistical Survey on Farm Management and Economy (Production Cost of Livestock)*.