“Research on technology development for improving feed self-sufficiency in Japan”

Review Report

General Comments of the Evaluation Committee

The NARO Research Program “Research on technology development for improving feed self-sufficiency in Japan” contained three areas of focus, “Development of utilization technology for domestic feed resources in Japan”, “Development of Japanese grazing technology” and “Development of precision feeding and waste management technology livestock with consideration for the environment”.

It is clearly evident that there are many talented and dedicated scientists working on the projects and that the latest technologies are being used to drive these forwards. Genetics (plant and animal) can nearly always lead to incremental improvements in cultivars and animals for production. Gains in efficiency in animal production is estimated at approximately 1% per annum, and would be accumulative. The genetics components of the program have performed well and has clearly made a significant contribution to the overall efforts a) although increasing the number of plant breeders to meet the challenges they have been set, might be warranted. Research into the use of combinations of grasses/silages and forages are also worthy experiments under local conditions and should lead to continued improvements in management practices.

Microbiome research is now at the point where a much deeper understanding of the underlying mechanisms of animal health and production can be identified, or eliminated as a significant factor. It could also be applied to waste management techniques, a necessary component to agriculture and animal production. It’s not just the ‘who’ that can be identified as being present during experiments, but also what they are doing (function). There are several projects that could gain further benefit from these types of analyses.

Overall, b) some of the techniques/methods such as new cultivars, ensiling techniques, waste management, and sensors/IT analyses could be used outside Japan and have a more global impact. In addition, overall, the program seems to be well-integrated. There are several research projects that potentially overlap with others, and in most instances these groups are working together.

The program has led to a large number of publications, and it appears that progress in this regard has been solid and will continue. This is to be commended, and helps lead to impact. c) Clearly there are several techniques/methods that are patentable (if not done so already) and once these are out more publications will likely follow.

To ensure the uptake of new technologies the results from the various projects need to be disseminated to the public to maximize their impact (e.g. ‘outreach’). This is being done in most the research projects, and is to be commended. d) It is, however, much better if they are accompanied by economic analysis. As mentioned during the review, manuals should not reduce innovation by farmers, the ultimate testers of the any technology or methods. Feedback should be sought from farmers using the new methods/technologies. In this regard, the addition of social scientists to evaluate and maximise the effectiveness of science communication, and to provide scientists with farmers’ and food consumers’ feed-back is an apparently new opportunity for NARO management to consider.

Taken together, the direction of the projects as a whole is aligned with the overarching goals of the wider program and is leading to practical solutions for use on-farm. The approaches are more than current 'best-practice' and are leading-edge in many aspects. Well done overall.

e) With regard to the programme's direction, consideration should be given to the efficiency. Efficient food production is unlikely to occur in small fields such as old paddies which then requires small processing plants to be developed. This is not *future proofing* of an efficient beef or dairy production system, although does employ people who might otherwise be unemployed.

A recent survey reported in New Zealand newspapers stated that "young people do not like manual work and only want to work in IT". If this is the same with young Japanese, then f) your research should be looking at increasing the scale of production systems, with larger machines, requiring many less workers. Innovative research might need to move away from the *traditional* mother-calf system for producing wagyu beef. Japan has the worlds' second highest cost of dairy production (and possibly beef production too). If your researchers are to make a difference, radical change is required.

NARO Response to the Comments of the Evaluation Committee (Alphabets show correspondence between comments and responses)

a) For improving feed self-sufficiency in Japan, it is necessary to breed new cultivars that can respond to climate change, cultivation in paddy fields, various diseases, and damage due to insect pests etc. To this end, we will seek to enhance forage breeding operations by securing personnel in the field of breeding, collaborating with private sectors, improving breeding techniques, and developing new personnel.
b) We believe that cultivar breeding, harvest techniques, and waste management techniques suitable for the climate in Japan can contribute to their deployment in other Asian countries with similar meteorological conditions as Japan. Moreover, we believe that our efforts towards the further sophistication and cost reduction of ICT and sensing technologies, in which Japan has great expertise, will contribute globally.
c) We will continue to work on accelerating patent acquisitions and research paper publications, and release our findings in the public domain.
d) The onsite verification trials currently in practice (1) analyze the economic performance with the participation of social scientists, (2) and receive feedback from farmers to connect to the technological improvements. We hope to continue and develop this managerial style of research.

e) We will strive to develop techniques that help to improve the efficiency, in accordance with the size and management philosophy of each farm.
f) Securing workforces is an important topic for Japanese agriculture, and we think it is necessary to develop techniques that are in line with the preference of young farmers. On the other hand, we will work to develop novel, efficient production systems, while preserving the favorable aspects (including quality) of the conventional production systems.

Section 1 Development of utilization technology for domestic feed resources in Japan

Project-1 Preparation of high quality whole crop rice silage using cultivars with high sugar content and high digestibility

Overall, this project appears to be on track to deliver its major goals (1, successful breeding of much-improved long-culm rice cultivars; 2, an efficient means of processing the new cultivars; and 3, the ability to

produce whole crop rice silage (WCS) from the cultivars. The uptake of usage of land area for WCS production has increased markedly since the year 2000.

The two new cultivars, Tachisuzuka and Tsukisuzuka have much-improved properties and represent a solid success for the project. Both Tachisuzuka and Tsukisuzuka good sugar content and Tachisuzuka shows improved digestibility over older cultivars. The improved total digestible nutrients for Tachisuzuka should aid in reducing concentrate costs in balanced diets for TMR-based animal production. This has been confirmed in an animal trial, which is a good result. This trial should be published, if possible.

Although the harvester seems to be an efficient solution to the preparation of WCS, and appears to also be able to be used for other crops (thus showing versatility), a) it is unfortunate that fine chopping is a separate process, adding to handling costs. Due to the small size being suggested for the ensiling process (6 mm) it might be important to get regular farmer feedback over the coming years. b) *"Time of day when silage is cut"* is also important. Cutting in late afternoon ensures soluble sugar content is at its highest. However, silage contractors will cut when it suits them, and if farmers only have small harvesters, they too will cut at any time of the day. So it will be difficult to manipulate cutting time to maximise soluble sugar content. Despite these situations, it is suggested investigating diurnal fluctuation in sugar content of the rice cultivars.

The Chikuso-2 strain appears to be a good solution (and cost-effective) for preparing WCS with several key positive attributes, especially its wide range of temperature for growth and effectiveness in preparing WCS (and rapid production of lactic and acetic acids during ensiling). It looks to be widely adopted throughout Japan (eventually), and thus is a very positive success.

Thus, overall, the project appears to have achieved strong progress towards achieving its primary goals. c) It is recommended to produce a pamphlet or 'e-document' summarizing what farmers can do and what they might expect from uptake of the technologies. It is also recommended that this group share their results and directly interact with those researching Theme 2 on 'Grass and forage crop breeding suited for Japanese climate'.

d) For further progress, it is necessary to pay attention to the cultivation of wintering crops after whole crop rice cultivation. In addition, it is important that other pasture/forage crop species are evaluated for TDN production/ha. TDN/ha is more important than quantity/ha. This "issue" becomes even more important if farmers reduce the amount of imported concentrates as self-sufficient feed production (forages) increase. Increasing the reaping height will be beneficial with regards to quality (not quantity). Consideration also should be given to the enhancement of the productivity and the improvement of the social value of WCS so that WCS can be produced without government subsidy. The rating is: **S – high quality and no revision needed.**

NARO Response to the Comments of the Evaluation Committee

a) The newly developed harvester enables us to perform harvesting and fine chopping in a continuous process. We have also confirmed that fine chopping does not have a negative impact on livestock, and we expect positive feedback from farms where it has been adopted.

b) No studies have ever reported a radical change in the sugar content of 'Tachisuzuka' and 'Tsukisuzuka' depending on the time of harvest. Therefore, currently, we do not believe that the high sugar content characteristic will be lost depending on the time of harvest. Nevertheless, we hope to examine the time of harvest at which the desired level of sugar content is obtained. Moreover, since fertilization management conditions and the number of days after ear emergence affect sugar con-tent, we would like to inform farmers of the conditions in which the sugar content is high.

c) A brochure with information on the (1) cultivars, (2) harvester, and (3) lactic acid bacteria is available from our website (http://www.naro.affrc.go.jp/project/results/files/2016juuten02leaflet.pdf). Moreover, we are strengthening cooperation with researchers of forage crop breeding to further improve this technology.

d) In terms of the cultivation of wintering crops after rice whole-crop silage (WCS) preparation, we will

develop a systematic technology for effective utilization of various forage crops other than the commonly grown wheat. In so doing, we hope to develop a cultivation system that could maximize the total digestible nutrients (TDN)/ha, as well as the utilization of new cultivars.

Project 1-2 Domestic production of rice, corn, and soybean for feed to reduce imported feed grain

In this project, three strategies for the domestic production of feeds were summarized, which together, will substantially decrease reliance on imported feeds. The rice-based method is more well-established (and appears to be highly successful with a dramatic increase in uptake), the corn-based in an early stage and the soybean just beginning. The early attention to the latter two challenges is to be commended.

Has the high labour input required to grow animal feed rice been factored into the economic feasibility of this research? a) Research that can lower the production cost should be done concurrently.

The approach taken to successfully replace imported grain (e.g. animal feed rice and DC) is a good step forward. Even without a price advantage, if it doesn't cost more, self-sufficiency will improve. b) Might be worth trying higher % supplementation rates for both ECS and HMSC. It may be beneficial to select corn cultivars that best match each climatic/environmental region of Japan. This would require on-going efforts, and feedback from both research studies (if possible) and farmers under local and 'real' conditions. Would be good to assess the benefit of increased lactones from corn-based silages and products. Consideration should be given to publish these results. It also suggested to test other silage inoculants (including those being produced within the wider collection of projects) which could lead to further improvements in production of rice feed silage and corn-based silages.

c) Research on the development of soybean varieties with high productivity is needed. The global increase in yield for soybeans worldwide has been estimated at 1.3% per year (Ray et al. 2013). Hopefully the yields from the cultivar that is to be developed by the soy-bean research group will meet the needs and expectations for the project, and afterwards. The two-step growth of Italian rye grass followed by soy beans appears to be a solid idea and every effort to improve production must be undertaken, although better grazing and silage management (i.e. grazing/cutting before it becomes too mature) will lower, but not remove, the need for soy-type products. For further progress, d) consideration should be given to trying to use this strategy more widely across Japan (albeit this might require different rye grass and soy bean cultivars combinations).

The group has produced several technical manuals; this is to be commended, as it will help to ensure maximum impact to farmer-the ultimate end-users of the project. e) Risk of subsequent crop failures in these systems should be mentioned especially in the manual. The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

a) In terms of research on forage rice, we will work on the re-duction of production cost as the most urgent issue to solve.

b) In terms of research on maize for feed grains, we will endeavor to develop new cultivars and cultivation techniques suitable for grain harvest, as well as silage inoculant, and to elucidate the characteristics of livestock products. In doing so, we will take advantage of empirical research in our collaborations with farmers, and aim to advance our research while constantly receiving feedback from farmers. We will actively publish the results as well.

c, d) For research on forage soybean, which is our future challenge, we will approach it from every possible direction to increase the harvest index. In particular, we would like to improve the chemical-free production methods required for for-age soybean, with the aim of expanding the areas where these methods can be applied.

e) We will try to disseminate the technologies we have developed so far and describe the risks associated with these technologies in the updated version of our technical manuals.

Project 1-3 Grass and forage crop breeding suited for Japanese climate

This presentation provided a nice history of the introduction and use of grass and forage crops in Japan and the issues surrounding the variation in climate. Excellent progress has been made with five classes of cultivars (Natuhimuka, Kyushu 1, Nou 3, Nakei 1, Hokkai 1, Nakou 907, Isan, Sniper) with either better resistance against disease, improved chemical composition, breeds with introduced genes, warm season grass and nematode suppression. a) Might be good to have a Mission Statement reading something like: *"To breed pasture and crop species to raise feed self-sufficiency to 70% and 90% in confinement and grazing systems respectively by 2025".* This then sets the magnitude of the challenge and focusses thinking on the big picture issues. It appears that pasture management by many farmers in Japan is poor, yet a few farmers have exceptionally good management. So, b) what is the goal for breeding – to provide for average farmers or for the best farmers already using the capacity of existing cultivars and wanting to go further? Many Japanese farmers use little or no chemical fertiliser on grazed pastures and apply slurry at the end of the growing season. Further, they graze and cut pastures when they are far too mature. c) Unless farmers change their management, then should the grass breeding programme be conducted in similarly poorly-fertilised and managed soils?

Concerning breeding goals, d) further adaptation to expected climate change are likely to be needed, and highly producing and cultivars/germplasm that are stable would be very beneficial overall to Japanese agricultural. The use of rice field for forage cultivation will increase, and in response to this, e) the development of flood-resistant cultivars is also actively required.

Emphasis on ryegrass breeding is to be applauded as a means of improving pasture quality for livestock. Success depends upon adaptability to local climate, which itself is evolving. Good progress achieved with Kyushu 1. Use of the cultivar in the two-step (double-cropping) production of soybean forage could prove beneficial. Don't give up on improving ryegrass for Doutou region as it's high quality attribute is greatly needed! Even meadow fescue may be better than timothy for grazing.

f) The Nou 3 low nitrogen cultivar could potentially be used on other Western countries, which has had problems with excess nitrate run-off and excess production of nitrous oxide emissions (and more widely in Japan). Research into getting these traits into other suitable hosts could prove beneficial.

The average increase in WSC in the new orchard grass cultivar Esajiman which was targeted to aid production in very Northern areas of Japan is noteworthy. Although this species is not of great merit in grazed pastures, if Esajiman is more palatable AND has a reduced tendency to develop seed heads then it will be useful. g) Rust may need to be bred out of this species and the leaf: stem ratio increased.

h) It is to be hoped that Hokkai 1 lives up to expectation of having a higher quality than older varieties and that its productivity is also high, as this is needed in Hokkaido. This is very promising.

i) Consideration should be given to increasing the seed productivity of Nakei 1 for the 'warm region' south of Hokkaido.

The new waterlogging-resistant Na110 corn cultivar would appear to be a distinct advantage in using in rice paddies. j) It seems that more work might be required to resolve any unfavorable traits due to the backcrossing, and this may require further research past the end of this project.

k) The oats Sniper cultivar could prove useful in other countries.

The Tohoku perennial rye grass strain appears to have promising regrowth and yield (DM) production qualities.

Taken together, the advances made by the grass and forage crop breeding project are substantial, and work should continue in this area. l) Consideration should be given to summarizing this information (either on the NARO website) or production of downloadable documents that outlines the availability and benefits of the new cultivars and the future direction of the project. The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

a) To address the effects of climate change and the development of cultivation and utilization techniques, it is important to continually develop improved varieties. Establishing a new cropping system, as well as cultivating pasture and forage crop varieties that respond to mechanization, enables stable production and improves the self-sufficiency rate of forage.

b, c) Since forage crops are cultivated as feed for livestock production, some of livestock farmers do not have the sophisticated techniques or heightened awareness of forage crop cultivation. However, based on the growing popularity of contractors and total mixed ration (TMR) centers, it is expected that the agriculture industry will undergo a shift from individual farming to organized farming in the future. In the process, a highly sophisticated forage production will be carried out through the division of labor among farmers, and cultivation and utilization will reflect the characteristics of crop varieties.

d, e) Climate change not only brings about new cultivation systems, but also presents unprecedented risks due to insect pests, storm and flood damage. To overcome these challenges, continuous breeding is required. There is a growing public demand for forage crop varieties for cultivation in paddy fields.

f) To enhance the pasture productivity and endurance, it is essential to apply an ample amount of fertilizers. However, the excessive use of nitrogen fertilizers may result in high nitrate–nitrogen concentrations in the forage that are injurious to livestock. One example of avoiding this in terms of breeding is seen in the 'Nou 3' Italian ryegrass. Sudangrass varieties encounter the same problem, and breeding in terms of reduced nitric acid concentration has already begun. There is a good prospect of selling varieties with reduced nitric acid concentrations abroad through private seed companies.

g) Although selection of varieties resistant to "rust disease" has not yet been sufficiently undertaken in Hokkaido, the selection for such varieties has already been initiated at the Tohoku Agriculture Research Center. Leaf-stem ratio is related to seed production so we will endeavor to improve varieties from this perspective.

h) Despite the high-quality and high-yield characteristics of 'Hokkai 1', the cold-hardiness has to be improved further to adapt to eastern Hokkaido regions.

i) We will pursue the breeding program of ryegrass to improve the seed production of 'Nakei 1'.

j) Further back-crossing of 'Na110' is necessary. However, we have currently prioritized on the effective introduction of related traits to breed moisture-resistant varieties.

k) This has also become an interesting topic of discussion in the field of Nematology. We would like to determine how the oats Sniper could be useful in other countries upon elucidation of the mechanism of action for nematode inhibition.

l) We will actively disseminate the information we have accumulated so far through our website.

Section 2 Development of Japanese grazing technology

Project 2-1 Grazing technology of beef cattle for abandoned farmland

In this project efforts are being made to develop grazing technologies to enable the better utilization of abandoned agricultural land. The ideas include: small-scale rotational grazing of distributed lands, establishment of better forages and their utilization, software for estimating grazing potential, and examination of year-long forage supply techniques. Taken together the techniques appear to provide a credible solution to the more efficient use of land for supporting animal production. Currently it has been limited to summer use, but a new direction seeks to extend this to full-year.

A very interesting project that has been well designed and implemented to meet a political prerogative. a) <u>It will help to utilise retired farm/crop land but, does little to improve efficient livestock farming in Japan. Utilising taste panels and education processes to change population preferences is important and needs to be</u>

well funded within this Project. A social science group might be needed to do justice to this work. Close collaboration with livestock nutritionist is also important.

Although the small scale rotational system (fencing, solar power, supply, etc. with mobile feeder unit) makes good sense as a solution to using the abandoned land, which no one would want to see not being used, b) was it necessary to develop a solar-powered electric fence system when these are readily available on the world market? Linking a water pump to this fence system is a good step, since a good daily water supply is essential.

It is apparent that pasture species that can stand up to grazing on wet, poorly drained paddy soils are required. This team has made progress in selecting species that meet this need. However, the assumption is that beef cows don't require good quality feed. Maybe this is true, but well-fed cattle, beef or dairy, will do very much better on top quality forage species, where we know that 'top' temperate species can have a similar quality to imported concentrates, given best management practices. c) Improving soil conditions and drainage so these better species can be successfully grown and utilised by grazing, would be one new direction to consider. Have you considered soil conditioners and introduction of earthworms?

The estimation technique for grazing capacity on the small-scale areas would provide benefits; and greater uptake by farmers would lead to greater impact. The calculation sheet appears to be a very useful guide for estimating grazing capacity on farms. d) Having a good database of a wide range of pasture species' growth rates will be necessary. But how relevant will the growth rate data be, given many farmers have poorly managed pasture systems?

e) The dissemination of manuals would help farmers maximize their gains of using the technique and help new users to ease into the technique. In the very-near future drones could be used to quickly estimate grazing capacity, using near-infrared and/or multispectral systems. Drones are increasingly being used in New Zealand to examine conditions on farm, which has similar hilly topography as is widely present in Japan.

Very interesting work with lignin-removed wood products. Hopefully this will become a world-wide option as a means for farmers to provide cheap energy for livestock, from land that cannot be grazed (steep forest-covered land). f) Collaborative work with the NARO animal nutritionists will be required. In addition, would be interesting to look at the microbiome effects, if any, and for any effects on animal production. May need further optimization to improve the use of it with other feeds. Might be worth investigating the lignin-removal technique on an array of tree species (such as *Pinus radiata* and eucalyptus species?) and/or other less-digestible feed stocks.

AI and ICT approaches are true science opportunities. It is recognised that it will be young new farmers who will adopt such technologies. However, whatever is developed has to contribute to growing and utilising more, higher quality feed, preferably for grazing, but also for ensiling. g) New, more profitable and sustainable farming systems are needed in the very near future. The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

a) With the increasing demand for red meat as consumers become more health conscious in recent years, discussion is already underway as to the kind of meat quality to be achieved in Japanese beef production. It is necessary henceforth to advance these discussions in order to organize a production system that suits the taste preferences of consumers. We have previously organized a "taste panel" to assess different milk products, and on that occasion, products that incorporated grazing in the production process received favorable consumer evaluation. Education on food, including its production process, is important, and is being implemented in Japan as "dietary education". In terms of beef production, however, it is necessary to strengthen education that is tightly linked to grazing. We also believe that it is necessary to further strengthen partnerships with groups of social scientists and animal nutrition researchers to achieve this goal.

b) We think that it is necessary to develop a small scale rotational system that is suitable to specific conditions in Japan particularly in the case of grazing in abandoned arable fields. We have shown that the method of linking a feed and water unit to a photovoltaic fence system is an efficient strategy for energy saving and for providing a stable supply of drinking water to livestock. It is therefore a good example of a technological development achieved through a combination of existing devices.

c) Grazing in abandoned arable fields, as presented in this review, is based on the implementation of drainage measures for paddy fields. The drainage techniques for this purpose, such as open ditch development, are presented in the manual, and we are selecting grass species that can be grown in dry fields. However, grazing in areas that require extensive drainage measures is not recommended due to the cost as well as the risk of injury to livestock due to waterlogged soil. In terms of soil amelioration, we think that it is not necessary to improve the soil nutrients in abandoned arable fields because these lands are originally agricultural lands, and hence are fertile in most cases. However, an extended period of grazing may promote the worsening of soil physical properties due to livestock trampling, and we suspect that measures for soil aeration may be required in the future. Introduction of earthworms is not necessary because most if not all soils are already inhabited by earthworms.

d) Since the Japan archipelago stretches horizontally and has a wide range of climate conditions, it is difficult for farmers to understand the potential of their agricultural lands according to the climate. It was therefore difficult to compare the production levels in each region so we had not discussed this matter. The calculation sheet for carrying capacity provides concrete information on the production volume for each grassland according to the climate in each region, and thus helps the farmers to understand the potential of agricultural lands. Farmers can estimate their production levels based on the calculated production volume, allowing them to improve their production management using the manuals we developed for that purpose. We are also developing a cultivation support program to assist the farmers in conducting more appropriate cultivation management.

e) The application of unmanned aerial vehicles (UAVs) to grazing management practices, including pasture plant cultivation management, greatly contributes to the enhancement of production efficiency. To this end, we are developing imaging techniques using AI, as well as information integration techniques via ICT. However, we are developing these technologies with consideration of the balance between the benefits and the costs to potential users.

f) We also have high expectations for the future development of lignin-free forage crops. In partnership with researchers in the area of animal nutrition and metabolism, we are aiming to elucidate their effect on a group of rumen microbes to confirm the efficacy of lignin-free forage crops, while discussing appropriate compensation rates. Furthermore, research on the expansion of the application to unused tree species will be promoted in collaboration with the private sectors.

g) Our goal is “to produce high-quality beef in a cost-effective fashion”, and as a means to achieve this goal, we have focused on the “grazing” factor. For this, the challenge is to provide the “best forage crops” on an “optimal time frame”, and it is difficult to achieve this over vast agricultural lands (grazing lands). We expect AI and ICT to be complementary technologies that will solve these issues. In addition, since “explicit knowledge” of technologies using AI or ICT exemplifies managerial tasks that have been carried out using one’s “experience” or by inherent “hunches” in grazing, it is effective in acquiring techniques for novel users. We are planning to advance the research and development of this subject while clarifying the “means” and “ends”.

Project 2-2 Development of dairy cattle grazing technology adapted to the climate of Japan

In this project, the aim is developing and improve dairy grazing techniques that are more flexible to deal with Japan’s range of environmental and climatic conditions. Several strategies have been employed: intensive grazing techniques for mid-sized dairy farms in cold areas, improving use of public pastures,

examination of traits in grasses for grazing, development of a grazing management technique, examination of marker traits in milk to aid management and dissemination/production of manuals incorporating the project's data for outreach.

a) Having more Japanese farmers adopt grazing systems is a top priority for improving profitability, raising feed self-sufficiency and improving social outcomes. As stated, having sufficient grazing land near the milking parlour is a limitation – true. b) With 200 farmers leaving the dairy industry each year, different land ownership opportunities need to be explored. In New Zealand sharemilking; cross-leasing, equity partnerships and land amalgamation are common approaches to overcome this limitation. c) Social scientists, industry leaders or government administrators could look into these opportunities. Collaborative development of this Research Project with owners of Public Pastures is one suggested change in research direction. Why not explore such opportunities within Honshu and elsewhere to efficiently raise wagyu calves for finishing and, in general, dry stock for dairy farmers? A very efficient grass farmer in Hokkaido, claims he can produce milk far more efficiently compared to the average. Your team is well placed to provide grazing opportunities for many more farmers to make a difference to their business and to the dairy industry. *Manuals* apparently tell farmers that you can make only 2 cuts silage/year. The quality of this silage is poor, whereas farmers who make 3, or even 4 cuts/year, have very high-quality silage. Further, combining silage and grazing paddocks into one whole-farm management system makes huge sense. d) This might not suit Timothy so better suited grasses will be needed. Is the best advice being given in the Manuals?

The new meadow fescue cultivar appears to be a nice breakthrough in enabling faster and more reliable growth after winter cold months, and is a good result (improved annual TDN production) for aiding intensive grazing technique in cold regions. e) It is hoped that high yielding, high quality pastures can be found to replace, or at least complement Timothy and Orchard grass. Festulolium, Meadow fescue and DouTou ryegrass present opportunities in this regard.

Extending the grazing season might also be aided by use of forage crops such as fodder beet, and brassicas which can be grown in summer and fed in November/December (Hokkaido) once pasture has been eaten. f) All of the options being researched, and those suggested, will increase feed self-sufficiency through better quality and greater quantity. Good work.

The productivity improvements in the utilization of public pastures, often typically sloped, looks to also be a solid improvement, with easy use. g) Would be good to see a 'manual' for its use to help with uptake. Similar systems (adapted to their own special conditions and animals, etc.) could be useful in other countries with a high degree of sloped grazing land (e.g. UK, New Zealand, central Europe, etc.).

The GIS and ICT approach to increase farming efficiency is commended. It will enable new limits to be set for improved land use, especially on large Public Pastures. However, good farm management is the first requirement on any farm, with computer technologies coming later.

It is interesting to see the CP map of a paddock, h) but what fertiliser and at what application rate will change CP%? Possibly the map indirectly relates to legume variability. In this case potassium or lime may help lift CP in the yellow and red zones. Applying N might only increase production and have no impact on CP. Science has to be done in advance of demand, but be sure you provide tools that farmers will use.

The comment about labour saving using precision fertilising might well be true but, based on year-round labour costs, this saving is insignificant. Creating these maps would take longer than applying the fertiliser! i) Besides, why not have a contractor apply the fertiliser using GPS-driven variable rate equipment on his truck? This is common in New Zealand.

The knowledge of phyt-1-ene and sialic acid in milks should be able to be used for marketing milk. j) It is, however, foreseen that there will be very strong opposition to use of these characteristics to define confinement and grass-fed Hokkaido milk because not all Hokkaido milk comes from grazing cows.

TMR Centres are becoming more popular but they do not reduce farm costs, nor do they reward a farmer who makes high quality silage, as his silage is shared amongst all TMR shareholders. Belonging to the TMR Centre also commits the farmer to using the TMR Centre products in spite of summer pasture being cheaper.

As you discussed, this matter is being addressed in some regions. TMR is a good concept for sure, but not necessarily a good business choice, especially over summer. k) Is there a research challenge here?

For the dairy industry to again grow, farming has to be seen as profitable, sustainable, and as providing a good lifestyle. Grazing goes some way towards this; seasonal milk supply goes even further; and l) seasonal once-a-day milking (OAD) might one day be the ultimate! OAD may produce less milk/cow but will be the most profitable system because farm inputs (costs) are lower and animal health benefits are high. Research has shown New Zealand-type cows are more suited to grazing than USA-type cows which, in turn, are better suited to confinement farming. m) To get the most from grazing, a breed change may be required. Some of Hokkaido's most profitable farmers keep their cows outside all year round. If this was to become "normal practice" there is little doubt profitability and lifestyle benefits will be large. Your team is well placed to provide new grazing opportunities for many more farmers.

n) These opportunities, along with your own ideas, offer good areas for new research that will *make a difference* to their business and to the dairy industry. But you need to meet with farmers to ask what they think of your ideas and to ask what they really want you to research for them. These meetings are extremely valuable. I understand you do have such meetings. The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

a-c) Grazing plays a big part in the improvement of profitability and forage crop self-sufficiency rate, and we will continue to promote technological developments in this field and popularization of the subject. In the future, we believe that it is important to work on the generalization of grazing in Japan, and hope to develop a technological system that permits differing degrees of dependence on the grazing grass, such as time-restricted grazing in order to respond to the land conditions for dairy management, as well as the growth and lactation stages of dairy cattle. In so doing, and in light of the increasing number of farms closing down their operations, we recognize the need to spend time performing socioeconomic research, including on public pasture utilization, in order to consolidate the farmlands around dairy barns.

d) Silage quality enhancement is an urgent issue, and we are planning to develop the technology and provide a manual for frequent use of orchard grass or perennial ryegrass.

e) In terms of introducing high-yield and high-quality grazing grasses, we will develop the technologies for utilization of new grass species and varieties focusing on the time for commercialization. We think these technologies are most applicable in areas used mainly for grazing. We also hope to develop a pasture utilization system combined with a silage-grazing dual-purpose paddocks for timothy or orchard grasses.

f) In grazing, we recognize that developing techniques for prolonging the grazing period is an essential issue, and there is an earnest request for this from dairy farmers. We hope to promote the research development and spreading of technology in the future, including the utilization of crops other than grasses that you have kindly recommended.

g) As for the grassland management-assisting system, we are going to permit the use of two selected pastures from among all applications for two years for free in an effort to improve the system from the user's perspective. The development of GIS and ICT technologies presupposes their usefulness for farmers and cattle ranchers, and we think that the use of tools such as smartphones and tablets, that can be operated by any farmer or cattle rancher, will help to popularize them.

h) As I have mentioned in the presentation, there was an example of a paddock where vegetation had been depleted and palatability lowered, and the application of nitrogen, phosphoric acid, potassium, and magnesium for two years allowed white clover to increase in number, and as you suggested, improved the palatability. On the other hand, farmlands indicated by the crude protein (CP) map are grasslands maintained without fertilizers for seven years, after the additional sowing of perennial ryegrass. During

the examination, patches in the white clover were not noticeable, and it is believed that there were only small CP fluctuations due to the white clover. Areas where the CP content was low tended to have low phosphoric acid and potassium levels.

i) The presentation lacked maps and an explanation of precise fertilizer application to the grazing land. These efforts aim not only to reduce the labor costs, but also to extract areas of the grazing land where not much grass has been eaten in order to investigate the cause, and to collect information for improvement. Since nitrogen fertilization on dung patches accelerates the rank growth of grass and weed, thereby further reducing palatability, this must be avoided at all costs on small-sized grazing lands in Japan. In the future, we will see increasing numbers of tractors with a built-in self-steering system or a variable-rate fertilizer applicator, especially among those owned by forage crop contracting companies. On the other hand, with the current grazing cattle management practice in Japan, where most paddocks are smaller than those in New Zealand, adoption of these systems has not advanced due to cost-effectiveness. Currently, few farmers understand the fact that a large truck can be used for agricultural practices other than transport on the farmland, including fertilizer application. For this reason, the safety and workability in hilly paddocks, the versatility and introduction costs, as well as the basic performance of a truck, must be examined in light of its relative merits.

j) Research on milk content that characterizes grazed cow milk has been conducted for the purpose of identifying or discriminating products in grazed cows, in view of the fact that confinement feeding is currently the most dominant form of feeding, even in Hokkaido. Since the level of milk yield generally tends to be lower for cows managed by grazing feeding than those managed by confinement feeding, we are conducting a series of studies on adding value to milk products in order to compensate for the decline in profit due to decreased milk yield. Even though the possibility of meeting some sort of opposition for its practical implementation cannot be ruled out, it is designed to develop into a technology that will contribute to the revitalization and sustenance of local communities, in partnership with local food processing and service industries, so we think that we will be able to gain their understanding.

k) The TMR center has been established with the aim of improving the quality of forage crops, as well as reducing working hours for the affiliated farms. However, as you pointed out, in farms that have already prepared high-quality forage crops, the benefit from forage crop quality improvement would be relatively small. We understand the need to solve this problem by combining research on forage crop preparation and feeding techniques with social scientific research on methods of co-existence between the TMR center management and the grazing farms that would provide benefits to both the affiliated farms and TMR sale destinations towards the sustenance and development of local communities.

l) We know that some grazing dairy farmers have a strong interest in once-a-day milking, and we would like to consider this topic in the future as part of our research on seasonal breeding for grazing.

m) We will also try to conduct research on the introduction and production of dairy cattle selected for grazing, as well as the simplification of feeding facilities.

n) We hope to determine the direction of technology development and select technology development plans by incorporating the earnest requests and opinions of dairy farmers more than ever.

Section 3 Development of precision feeding and waste management technology for livestock with consideration for the environment

Project 3-1 Control of rumen fermentation in dairy cows towards improving feed energy utilization

In this project Microbiome and transcriptome techniques were used to identify the core rumen microbes involves in fibre degradation. Several other studies have looked at the microorganisms that are common to most ruminants, and this study now takes this type of work to the next level, zeroing down on the microbes that do the hard work on digesting the fibre. In addition, the carbohydrate degrading enzymes (CAZymes)

have been closely examined, an area that needs more exploration, so as to be in a position to manipulate them to improve fibre degradation. The publication record form the studies is exemplary. In addition, cashew nut oil was used (and bromochloromethane, a chemical inhibitor) to examine the changes in the microbes with inhibition. These two compounds would be expected to work through different mechanisms (one directly targeting methanogens and the other indirect). Future strategies were outlined.

The work on identifying the organisms that form consortia with *F. succinogenes* identified several organisms, and is the first work of this kind. These are important types of studies, as consortia are required for efficient fibre-degradation. *F. succinogenes* is obviously a key member. This work continues with JGI, and should help extract more data about this. The transcriptomic techniques performed by the team validates the approach, in a manner that is increasingly being seen to be coming to fruition in with human microbiome studies. The data shed light on consortia of microbes that are essential for driving fermentation of feeds.

Using a chemical inhibitor (a halogenated compound targeting methanogens) as an example, a large shift in hydrogen was obtained (with expected increased propionate) which was associated with increases in hydrogen-consuming *Prevotella* and *Selenomonas* spp. Interestingly, no decrease in fibre-digestion was seen, and either a small increase or a 'not affected' outcome in *F. succinogenes*. A decrease has been noted in some other studies, including using cashew nut oil (Kobayashi et al. 2016). a) It is likely to be important to perform longer term studies to optimize the concentration of inhibitors so as to obtain a sustainable and long-term effect that reduces methane emissions while at the same time, not adversely affecting production parameters.

Cashew nut shell liquid (CNSL) is produced as a by-product in Asian countries amongst other countries (e.g. India, Viet Nam, etc.). This should help CNSL to be sourced relatively economically for routine use, and thus to potentially have an impact on methane emissions. Publications by this group indicate that CNSL maintains its ability to reduce methane emissions, which is a great result; others that have used technical grade (involving heating) have shown less effect. b) More research would be needed to investigate the effects of the various forms of CNSL, and indeed even its formulation and/or formation of pellets. Consideration should be given to chemically synthesize individual compounds of CNSL. Also, other phenolic acids may have similar activity, so it might be worth testing derivatives of the main phenolic acid parent compound.

Regarding future perspectives and ideas, the examination of the peri- to post-partum period is a good one, as this timeframe is crucial and of major importance to dairying. Aiming for greater feed conversion efficiency through understanding microbial digestion patterns is a logical step forward. It is, however, foreseen that a poor reproductive performance of cows as milk production increases. c) Better feed conversion might improve her nutritional status but to no avail if it only improves her milk production. Consider the big picture in conjunction with animal nutritionists.

The capabilities of this group in molecular and microbiological characterization of rumen microbiomes is exemplary. d) Hopefully these molecular techniques will continue to be used for the various projects outlined in the overall NARO project (Sub-acute rumen acidosis, etc.,) The rating is: **S – high quality and no revision needed.**

NARO Response to the Comments of the Evaluation Committee

a) Not much is known about the effects of long-term methane suppression, and it is one of the most important topic for discussion. We would like henceforth to keep this point in mind, and advance our research in a joint study with participating institutions.
b) Research on the structural analog, etc., of substances that have methane-suppressing effects is one field where great scientific progress can be expected. We hope to expand the research project on methane suppression, not to mention the present project, to a scale that allows us to verify the safety.
c) There is little doubt that adequate methane suppression in the rumen would contribute to the improvement of feed conversion, and it is also thought to be efficacious for the improvement of energy balance in an individual cow. To further coordinate our research with milk yield, we think that a broader research

collaboration that includes breeding improvement is necessary, and we have started this research collaboration.

d) In the course of our research, we have developed and advanced molecular biological techniques. In recent years, we have participated in a variety of projects for dairy cattle breeding management, and have started to use techniques obtained to assess breeding management. We hope henceforth to contribute to the improvement of breeding management techniques for dairy farming, not to mention methane-suppressing techniques.

Project 3-2 Improvement of nitrogen utilization efficiency by synchronizing ruminal supply of feed energy and protein in dairy cows

In this project, the synchronization of feed energy and protein was investigated with regard to nitrogen utilization. Two main experiments were performed, one involving predicted low synchrony compared against a high synchrony diet, and the other looking at low/high crude protein (both in dairy cattle). Another goal (and benefit to the overall project) was to examine ways to promote the increased use of self-supplied feeds.

Experiment 1 led to increased higher energy and dietary nitrogen efficiency (lower heat production and lower nitrogen excretion), which should lead to reduced use of expensive imported soy bean meal (and therefore would promote the use of local feed supplies). However, one negative outcome was that the higher synchrony treatment group diet showed a lower overall digestibility.

In experiment 2 use of the low crude protein (LCP) diet succeeded in achieving similar milk production levels to the high CP (HCP) diet, and reducing urinary nitrogen excretion. However, data suggests that the LCP was associated with reduced digestibility and a reduced metabolizable energy (ME). The latter is important for sustaining milk production.

Thus, a) although both experiments yielded mostly positive results, further experiments could advance the overall results and should be considered. Follow on experiments would appear to be warranted, to examine maybe further optimized diets for the high synchrony experiment (to improve digestibility) and for the LCP diet to see if conditions can be found to lower the impact on ME intake. b) Consideration should also be given to perhaps increasing the number of animals (currently at four in both experiments) to enable better statistical analyses. c) Hopefully the present experiments will be published soon.

The experiments could have significant impacts on greenhouse gas emissions, both methane (Exp. 2) and N-related (both experiments, but particularly Exp. 2), especially if the techniques are more widely taken up. d) It looks like there could be potentially useful interactions between the group of project 3-3 especially with lower protein diets with regard to greenhouse gas impacts.

Sounds like the Japanese Feeding Standard will be improved from these experiments and the additional points raised (e.g. energy efficiency for milk production, and amino acid metabolism in the mammary gland).

These experiments would appear to potentially benefit from microbial analyses, particularly Experiment 2. e) Consideration should be given to examining the microbial populations and their activity (transcriptomics) in future experiments such as these (and perhaps the already conducted experiments if appropriate samples have been stored). The rating is: **A – good quality and minor revision needed.**

NARO responses to the comments of the Evaluation Committee

a) Concerning the reduced digestibility, we have considered different feed ingredients and have further optimized the synchronization of feed digestibility in the rumen. The results obtained from our latest experiment revealed a successful improvement in the digestibility of a low-crude protein (CP) diet, as well as metabolizable energy (ME) intake.

b) Increasing the number of animals is ideal to facilitate statistical analysis of the results of our experiments; however, the number of animals for each experiment is limited by the capacity of our facility and by the

number of staff. On the other hand, making full use of our facility with a limited number of staff gave us high accuracy and repeatability in our data.

c) Publication of these results is an urgent issue.

d) In collaboration with the Project 3-3 group, we have already determined the greenhouse gas emission from the excreta of cows as part of this research project but we did not include it in our presentation. Thus, we hope that the evaluation will be based on the animal's performance and the results from manure management study.

e) Microbial populations and their activity strongly affect the ruminal digestion of feed and methane emission. Thus, in collaboration with the Project 3-1 group, we will analyze the impact of these microorganisms on ruminal fermentation and manure management in a future study.

Project 3-3 Manure management for greenhouse gas mitigation

In this project, four strategies were outlined, all showing excellent results with regard to enabling lowered emissions. The four strategies were: more accurate larger-chamber measurement systems for N_2O, a novel nitrite-oxidizing inoculation technique for composts, a carbon-fibre-based biofilm technique for wastewater treatment facilities and the use of a low-protein diet to lower emissions. The work has been well-published. Taken together the systems and processes should help Japan meet its national greenhouse gas reduction targets and enable more accurate inventory assessments. The impacts of these technologies are to be considered in Life Cycle Assessments.

The greenhouse gas measurement system (i.e. large dynamic chamber; Fukumoto et al. Bioresource Technology 2003) is a solid advance for the quantitative assessment of research experiments and on-farm emissions from waste processing operations. a) It will be interesting to see the results of its use more widely across Japan and looks to be a valuable tool for ongoing research projects. Other gas measurement systems were highlighted including hen feces composting system and a pit storage dairy cattle slurry. Real-life quantitative monitoring of greenhouse gas emissions is important for country-level inventory analyses and to assess ongoing improvements in techniques for lowering greenhouse gas emissions, whilst maintaining production.

The simple method for addition of mature composting inoculant into composts appears to be an effective mitigation technique (Fukumoto et al. JARQ 2015). It appears that the assessment of the compost that would be used for inoculation on-farm can be assessed by several simple kits (e.g. nitrite and nitrate concentration kits) and techniques. b) Once the technique is to a point where it could be 'rolled out' to the public then a manual/guideline should be produced. Consideration should be given to using molecular techniques to assess the microorganisms responsible.

The aerobic carbon fiber bioreactor method appears to be a cost-effective and excellent solution to reducing emissions from wastewater treatment plants (Yamashita et al. 2016). c) Consideration should be given to analyzing the microbial communities and/or their crucial nitrogen metabolism enzymes as they develop on the carbon fibers and compare this to concentrations of nitrogen intermediates (e.g. ammonia, NO_3 N_2, etc.) to gain a deeper understanding of the process.

The prospects for a lower protein diet contributing towards total lower greenhouse gas emissions, as a result from the low protein diet swine look promising, and similar technique may also help with other production animals. d) If the 40% reduction or similar impact can be obtained in the poultry and cattle production, then that would be a great result. The researchers should probably interact with others (if not doing so already) in the overall NARO program to ensure any synergies can be captured. Similar to previous comments, consideration should be given to examining, microbial communities in experiments where this could prove to be informative (e.g. the LCP experiment(s)).

LCA analysis (Ogino et al. 2013) are vital for examining the total impact of new animal husbandry methods in a holistic manner and this is to be commended since scaling from research *plots* to whole farm systems

usually introduces unexpected outcomes. The rating is: **S – high quality and no revision needed.**

NARO Response to the Comments of the Evaluation Committee

a) Composting treatment is the most popular system for treating cattle manure in Japan. Restrictions on the level of greenhouse gas (GHG) emissions varies depending on the climate condition and livestock species. We believe that efforts to reduce greenhouse gases begin by accurately measuring and presenting the emission status for each farm.
b) In creating a manual, it is necessary to extract the scope of application for a technology, as well as problems found through experiments etc. Moreover, we will consider microbial analysis using a molecular biological technique.
c) In terms of carbon-fiber reactors, consideration for microbial activities and gas emissions other than N_2O is required. They must be considered in conjunction with the research into demonstrating the manner of introducing it to farm facilities.
d) Research on GHG reduction via nutrition management, including amino acid-balanced feeding, has already begun in chicken production, dairy production, beef cattle production, and pork production. In these studies, in addition to the GHGs directly released from the management of animal wastes, the change in total GHG emissions in a system will be assessed using life-cycle assessments (LCAs).