The Study on the Organization of the Collective Farming-System by the Multi-Agent Model

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1. Introduction

In many rural areas, it has been difficult to secure the continuous leader from the individual farmhouse because of the labor shortage by the aging of the current farmers, the absence of the successor and so on. In such districts, to organize a collective farming-system[1] as the core leader of regional agriculture is wanted now (Figure 1 reference). Then, for attempting to spread out from the individual management to collective farming-system, it is indispensable that each farmhouse himself has problem consciousness to the present situation of the regional agriculture and to share a goal. In this point, we think that to enlighten the farmhouses by showing the effectivity of collective farming-system will become a very much valid method.

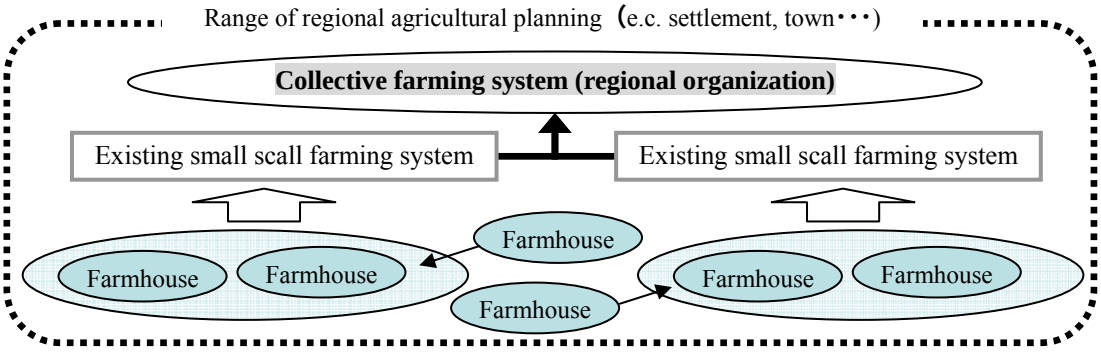

Fig.1 The image of gradual development from individual farmhouses to farming system

In this research, it applied the multi-agent systems as the analysis method of the complex systems of Japanese rural area and built the simulation model which forecasts some future situations of the regional agriculture (Agent-based Simulation Model for Agricultural Planning, hereinafter we called it " ASMAP"). Our purpose is illustration of the effectiveness of ASMAP by case study. The image of ASMAP (the artificial society) and the outline of the component are shown in Figure 2.

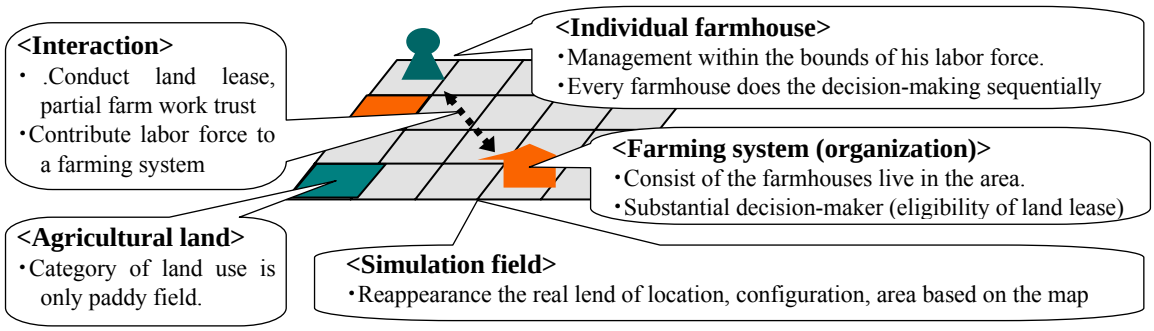

Fig.2 The outline of simulation field and component in ASMAP

[1] Collective farming-system means the sharing use of agricultural machinery and collaborative work by almost all farmhouses in the settlement. Strictly speaking, it is comprised in the meaning to integration of their accounting.

2. The Structure of ASMAP

(1) The suppositions in the artificial society

We provided the several suppositions for model building. A part of the main suppositions is shown below.

1) When organizing a farming-system, machine operators are composed only of farmer in the area.

2) Buying and selling of agricultural land is eliminated.

3) The Customary service charge and land rent remain unchanged and not changed by the negotiation.

4) All the farmhouses are management their land only about ten years and if it has pasted the span, the agricultural lands are treated "Abandonment cultivated land", it means an uncultivatable land.

5) The category of land use is only building land of farmhouses and paddy field. And then the external economy or diseconomy effects by each land use are eliminated.

(2) The decision-making flow of the farmer and collective farming-system

Decision-making entities defined in the model is individual farmhouse, individual farming-system, and integrated farming-system which the imaginary management agency composed some small size farming-systems. Figure 3 is the conceptual diagram of the decision-making entity in ASMAP, and the decision-making flow of them is shown Figure 4. So based on this flow, we described particulars about their behavior pattern or the definitional equation of agricultural income.

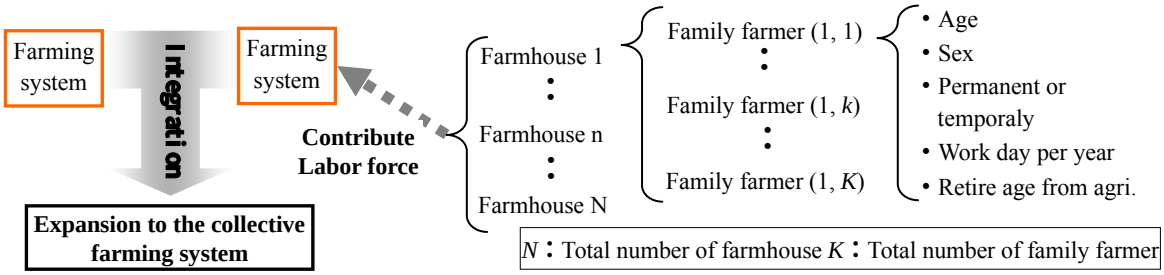

Fig.3 The conceptual diagram of the decision-making entity in ASMAP

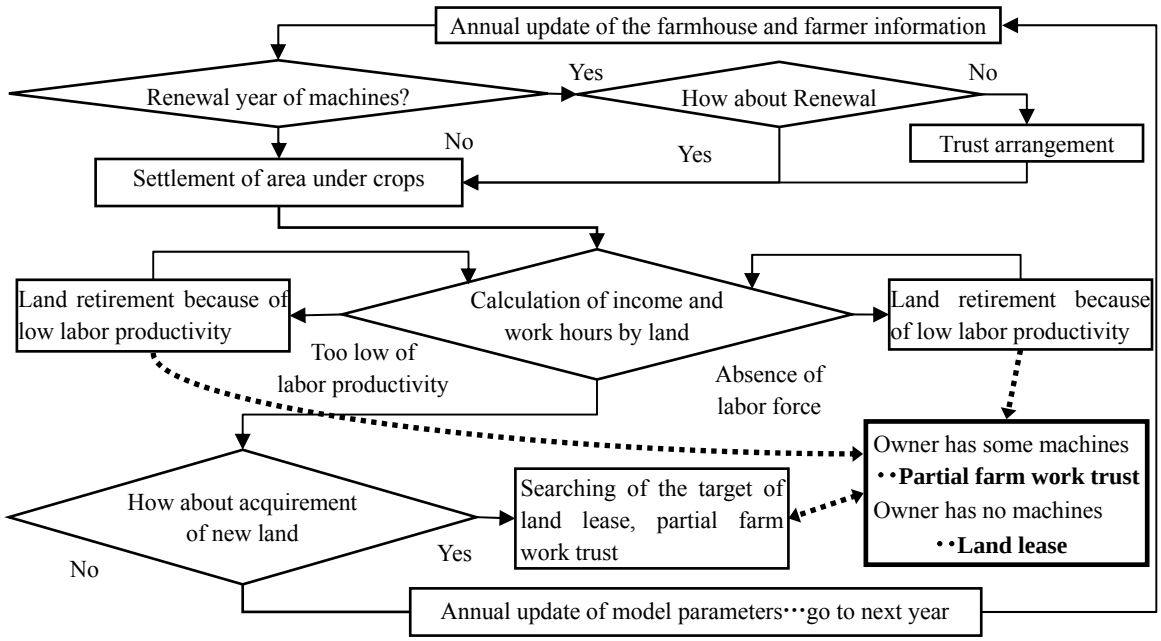

Fig.4 The decision-making flow of farmhouses and farming system

1) The annual update of the farmhouse and farmer information

In the simulation, every farmer is growing older like the real society by one year, and we sets the probability event of the retirement from agriculture (assuming about 80 years old) or mandatory retirement age returning home to be a farmer (assuming about 60 years old).

2) The definition in the annual available work hours for agriculture

In ASMAP, the total available work hours for agriculture of the individual farmhouse takes in *K*-person family laborers are defined as the sum of their annual labor hours. In a farmer (*n*, *k*)'s case, the number *n* means farmhouse's ID and the number *k* means farmer's ID in the farmhouse number *n*, the annual available work hours for agriculture on t years later from now ($E_{t(n,k)}$) are defined as expression 1. And those of the farmhouse number n ($L_{t(n)}$) are defined as expression 2.

$$E_{t(n,k)} = Q_{(n,k)} \times A_{(n,k)} \times (1 - Cont_{(OrgNum)}) \quad \cdots(1)$$

$$L_{t(n)} = \sum_{k=1}^{K} E_{t(n,k)} \quad \cdots(2)$$

Where $\boldsymbol{Q_{(n,k)}}$**:** The parameter which means work hours of one day for agriculture (from questionnaire), $\boldsymbol{A_{(n,k)}}$**:** The parameter which means daily work hours for agriculture (from questionnaire), $\boldsymbol{Cont_{(OrgNum)}}$**:** The contributory rate of labor force which each farming-system they belong to arranges (from interview), ***K*:** Total number of family laborers in the farmhouse number *n*.

3) Calculation of the agricultural income and the necessary work hours by an agricultural land

Based on the structure of the owner and the manager of the agricultural lands, we categorize them like Table 1 and Table 2, and defined the calculation method of agricultural income and work hours by each agricultural land. And then, based on the labor productivity by agricultural lands (agricultural income per work hours), every farmhouse ranks their agricultural land hierarchically. So when they think of land lease,

Table1 The agricultural land category based on the structure of the owner and the manager and definitional equations of agricultural income by each land

Owner	Manager	Operator	Category	Definitional equation of agricultural income (yen) Yr：Rice yield, Pr：Rice price, Cv：Variable cost, S：Crop Area, Pm：Machinery price, α：Rate of capital investment from another gain, D：Durable years of machinery, W：Machinery running area, f1：Land rent, f2：The Customary service charge
Self	Self	Self	Self	$\left(Yr_t \times \mathrm{Pr}_t - Cv\right) \times S_{(X,Y)} - \sum_{k=1}^{3} \left\{ \left(Pm_k \times (1-\alpha)\right) \times S_{(X,Y)} / \left(D_k \times W_{kt}\right) \right\}$
		Others	Charge	$\left(\mathrm{Y}_{\mathrm{r}\,\mathrm{t}} \times \mathrm{Pr}_{\mathrm{t}} - \mathrm{Cv}\right) \times \mathrm{S}_{(\mathrm{X},\mathrm{Y})} - \sum_{\mathrm{k}=1}^{3} \mathrm{f2}_{\mathrm{k}} \times \mathrm{S}_{(\mathrm{X},\mathrm{Y})}$
	Others	Others	Lease	$\mathrm{f1} \times \mathrm{S}_{(\mathrm{X},\mathrm{Y})}$
Others	Self	Self	Borrow	$\left(Yr_t \times \mathrm{Pr}_t - Cv - f1\right) \times S_{(X,Y)} - \sum_{k=1}^{3} \left\{ \left(Pm_k \times (1-\alpha)\right) \times S_{(X,Y)} / \left(D_k \times W_{kt}\right) \right\}$
	Others	Self	Trust	$\sum_{\mathrm{k}=1}^{3} \mathrm{f2}_{\mathrm{k}} \times \mathrm{S}_{(\mathrm{X},\mathrm{Y})}$

・ The subordinate k means following. 1is tractor (plowing), 2 is transplanter (planting), 3 is combine (mowing).
・ With reference potential, Tm_k equal to 1 if he operate the machinery work (*k*) indeed, and not 0.
・ Each parameter is set as unit quantity per 10a. And subordinate (X,Y) means the value about the land located coordinates (X,Y).

Table2 The agricultural land category based on the structure of the owner and the manager and definitional equations of work hours for agriculture by each land

Owner	Manager	Operator	Category	Definitional equation of work hours for agriculture (hour) Tc：Work time for except machinery, Tm：Work time for machinery, δ：Weighting parameter for distance from home to land, R：The parameter of scale merit, d：distance from home to land, dum：Dummy variable for work trust
Self	Self	Self	Self	$\left\{Tc + \sum_{k=1}^{3}\left(Tm_k \times R_{(X,Y)}\right)\right\} \times S_{(X,Y)} \times \delta^{(d(X,Y)-1)}$
		Others	Charge	$\left\{Tc + \sum_{k=1}^{3}\left(dum \times Tm_k \times R_{(X,Y)}\right)\right\} \times S_{(X,Y)} \times \delta^{(d(X,Y)-1)}$
	Others	Others	Lease	0
Others	Self	Self	Borrow	$\left\{Tc + \sum_{k=1}^{3}\left(Tm_k \times R_{(X,Y)}\right)\right\} \times S_{(X,Y)} \times \delta^{(d(X,Y)-1)}$
	Others	Self	Trust	$\sum_{k=1}^{3}\left(Tm_k \times R_{(X,Y)}\right) \times S_{(X,Y)} \times \delta^{(d(X,Y)-1)}$

・The range of R is 0.7 to 1.0. The value of δ is about 1.03. It was decided empirically. And d is measured by direct distance in the simulation field.

contract farming, they select the most gainful land in sequence. And when they think of abandonment of cultivation, they release the land of lowest Labor productivity in sequence.

In ASMAP, the farmhouses are make judgments of abandonment of cultivation because of ①physical reason which accompanies the decrease of the labor force and ②economic reason that the price of rice falls from the permissible-level. In addition, the farmhouses which have redundant labor forces project land lease or contract farming by selecting from the group consisting of idle fields abandoned by other farmhouses. However, we supposed that agricultural land lease isn't formed if the desired partner and the receiver in the agricultural land don't agree. That is to say, we want to reflect the picking and choosing relation to the partner of the agricultural land lease.

3. The Framework of the Simulation Analysis

(1) The overview of the survey area

The survey area of this research is H district in Hyogo Prefecture, which is small settlement located in Hyogo Prefecture Midwest and the flat agriculture area. The number of total farmhouses live in there is 116 and the one of total population of farmers is 724 pieces. And the total cultivated areas is 56.96 ha (From the agricultural census card in 2000). In H district, there are four independent farming systems and they administrate discrete quarter of total area and farmhouses dwell in the each area evenly (Table 3 reference). For establishment of sustainable management entity on regional agriculture, they have held active discussions about integration of them focused on 3rd collective farming system, the most systematical organization (at the moment they are still independent).

Table3 The comparison of four farming systems

	Number of farmhouses	Cropping area	property
1st farming system	24	12.45 ha	Semi systematic
2nd farming system	31	14.38 ha	Systematic softly
3rd farming system	24	14.50 ha	Systematic
4th farming system	30	13.61 ha	Semi systematic

(2) The frame of the analysis

As shown in Table 3, individual management intention is strong among the constituent farmhouses of only 2nd farming system. Toward the achievement of integration of four collective farming systems, we are convinced of that the equalization of strength as an organization of them and then helpful information supplement must be indispensable.

In this research, with the aim of political proposal and enlightening information supplement, we attempted some comparative analyses on the effect which was partial integration and holistic integration of farming systems. Incidentally, the simulation period in this research was 20 years.

First of all, to grasp the present state and the intention of the individual farmhouse, we worked out the questionnaire survey to the 2nd farming system (Table 4 and Table 5 reference[2]) and interview for leader of it. In ASMAP, we set the status and the intention of the farmhouse in the early stages of the simulation based on these answers. Hereafter in this simulation analysis, we used these answers and values[3]. In addition, some initial values of main parameter on the simulation are shown to Table 6

Then, in addition to aforesaid comparison by the difference of scope of the integration, we also compared by the difference of strength as an

Table 4 The Term of questionnaire survey and answer form

Term	Remarks
About family farmer, heritor and their working result	Age, Sex, Living together or not, Possession of other avocation, average number of work day a year, and so on.
The intent for operator in collective farming system	The rate of contribution for organizational active, and the intent executory.
The location and area of their agricultural land	The area of their agricultural land in distinction from leased land to own.
Possession of machine	Possession of machine (tractor, transplanter, combine) and the number of using year of them, the intent of renewal of them.
The intent of expansion of their farm area	The intent of land lease, partial work trust, and continuance of agriculture.
The level of rice price of feeling their limitations	The level (concrete amount) of rice price of feeling their limitations.

Table 5 A piece of the result of reply for questionnaires

questionnaires	Reply (all number is 24)
Possession of machine (number)	Tractor…19, Transplanter…12, Combine…12
The number of intent to renewal of them	Tractor…5, Transplanter…1, Combine…2
The area of partial work trust executory	Expansion…1, Status quo…3, decrease…2
The desired partner for land lease	Farming system…18, individual farmhouse…6, Reluctant to lease…6, Other…1

Table 6 The standard values of main parameter

Parameter	Varue
Yield point(10a)	530 (kg)
The work hours for except machinery(10a)	15 (hour)
The work hours for machinery(10a)	3.5 (hour)
The span of management for limit land	5 (year)
Rice price(60kg)	13,800 (yen)
The degrading ratio of rice price (per year)	2 (%)
The fee of plowing on work trust (10a)	10,000 (yen)
The fee of planting on work trust(10a)	13,000 (yen)
The fee of mowing on work trust(10a)	13,000 (yen)
The variable cost	25,000 (yen)
The contract years of land lease	10 (year)

[2] Fundamentally, we wanted to work out a questionnaire survey to all farmhouses. But because of the temporal and economic restriction, we could not help narrowing the object region of this questionnaire.

[3] Consequently, we assumed the every structure of other three farming systems based on the results of questionnaire, interview and document data on the 2nd farming system by necessity.

Table 7 The structural outline of hard, middle, soft organization

Organized strength	Some character trait of each farming systems			
	Possession of machine	Intent of machine renewal	Join to organized active	Rate of labor contribute
Hard	Nothing	Nothing	All participate	100%
Middle	About 30%	About 50%	All participate	80%
Soft	Reflection of reality	Reflection of reality	applicant	60%
Common supposition	・Don't leave fallow or reject of work trust by right and wrong of labor productivity. ・Always possess the machine fully and renewal necessarily. ・The constituent member don't stop participate by right and wrong of labor reward.			

organization after their integration. Concretely speaking, we assumed next two cases. First, the strength as an organization of integrated farming system turns the weaker level of previous organization. Second, it turns the stronger level of previous organization.

To define the character of the organization of each farming system, we classified these farming systems into three levels with reference to Table 3, and named 3rd farming system "hard organization", 1st and 4th farming system "middle organization", 2nd farming system "soft organization" tentatively. And then, we designed their structure and behavior in ASMAP distinctively by drawing on their actual performance or terms of organization (Table 7 reference). And as the evaluation index of the simulation result, we adopted labor productivity to be able to observe some differences of simulation result clearly.

4. Simulation and Prospect

(1) Simulation 1 " If the present situation were maintained・・・?". (It is standard case)

The forecasted land map on the standard case is shown Figure 5. In the case, it was forecasted that many abandoned cultivated lands and marginal kept land which their owner feel their limitations to manage would become obvious broadly. As the figure about transition of the area of abandoned cultivated lands (Figure 6 reference), the area of them at the 20 years later was forecasted to 6.5 ha. This value is equivalent to about 45% of all the cultivated areas in 2003 (the area of abandoned cultivated lands was 0). Farther more, we apprehend the elicitation of more potential abandoned cultivated lands by "the negative chain" which accompany the disturbing land consolidation by deregulated abandoned cultivated lands or weakening of management capability of irrigation system. In respect to the average labor productivity of farming system (total income / total work hours), It was clear that the level of labor productivity was proportional with the strength of it (Figure 7 reference). Because of not only degradation of agricultural income by the downslide of rice

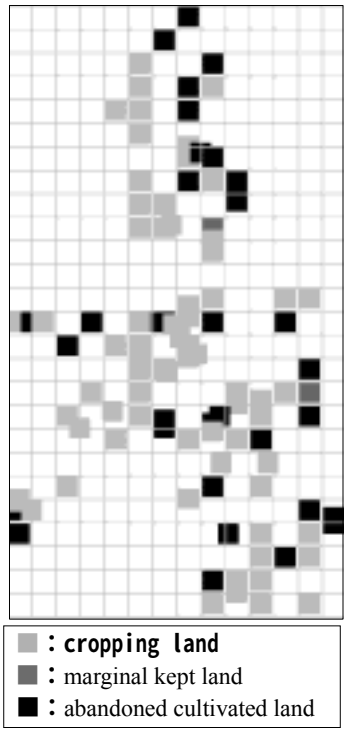

Fig.5 The forecasted land map on the standard case

price, but also the smallness of management scale of each farming system, it was forecasted that it would be inevitable for each farming system to suffer some deterioration of profitability in the long term.

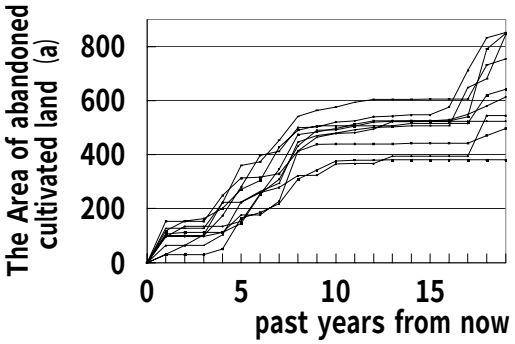

Fig.6 The transition of the area of abandoned cultivated land

※ Each line in this figure means the result of each one trial. In this research, simulation result means the average score of ten times trial.

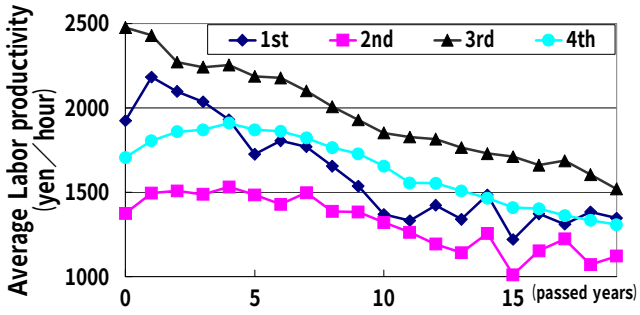

Fig.7 The transition of the labor productivity (The case of continuance present situation)

(2) Simulation 2 "The effect forecasting by integration of the collective farming systems"

1) The partial integration

With similar evaluation index, we analyzed the simulation result of partial integration of the collective farming systems (Figure 8 reference). As shown in Figure 8, there are some effects on labor productivity in comparison to the standard case, but they were not that much large. In addition, there were not so many differences between the hard organized farming system (partial integration_1) and the soft organized farming system (partial integration_2). These results gave precise suggestions to have to organize more large scale farming system.

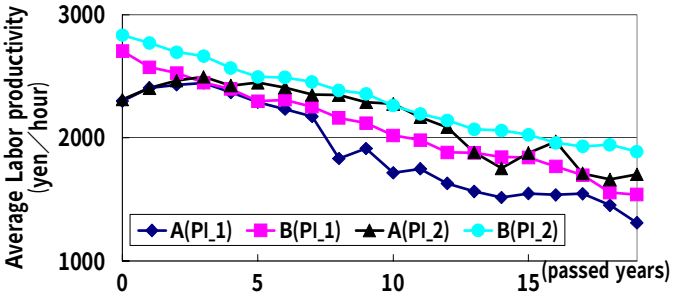

Fig.8 The transition of the labor productivity (The case of partial integration)

※ A means the integrated farming systems consist of 1st and 2nd farming systems. On the other hand, B means the integrated farming systems consist of 3rd and 4th farming systems. “ PI_1” means that the integrated farming system turns the weaker level of previous organization. “ PI_2” means that the integrated farming system turns the stronger level of previous organization.

2) The holistic integration

The simulation result of holistic integration of four farming systems is shown in Figure 9 (The forecasted land map of this case was omitted because of space limitations). At this case, I know that the gradual decrease of the labor profitability is seen, but the level on 20

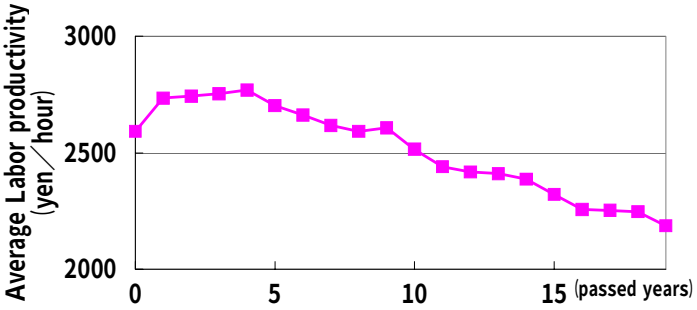

Fig.9 The transition of the labor productivity (The case of holistic integration)

years later still exceeds about 2,000 (yen/hour). It is clearly high level than the cases of aforesaid partial integration. Actually, now in H district each farming system sets the labor reward about 1,200 (yen/hour). So it would be only this case that farming system could maintain the reward for constituent member in the future.

5. Conclusion

The abstract of this research is as following. First, it was forecasted that if the present situation that each small scale farming system continued without integrating, it isn't possible fully to accommodate the deterioration of the profitability which accompanies the fall of the rice price, even if they taken the opportunity afforded by retire at the individual farmhouses and so on to promoted the integration slowly. And in was clear that when planning the integration of the collective farming systems actually, the effect for agricultural income depended significantly on the scale of integrated farming system.

When the different organization of the efforts and the policy integrates, the larger in scale it becomes, the bigger the cost of consensus building becomes, the simulation results of the this research must be prospective greatly for playing the role of promotes organization as the enlightenment information at the relation farmhouse. We believe that ASMAP has a high potential about showing the indicator to the organization of the regional agriculture. And for that purpose, we must validation the effectiveness of ASMAP at real society.

Acknowledgment

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Reference

1) Ryohei YAMASHITA, Satoshi HOSHINO, Haruhiko IBA：『Development of the Simulation Model on Collective Farming System by Multi-Agent Systems』 , The Journal of the Association for Regional Agricultural and Forestry Economics, Vol.41, No.1, 2005, pp 60-65.

2) Ryohei YAMASHITA, Satoshi HOSHINO：『Comparative Analysis by Simulation about the Effect of Integration of farming systems』 , The Journal of the Association for Regional Agricultural and Forestry Economics, Vol.42, No.1, 2006, now printing.