Application of a New Procedure to a Project, and Discussion
—On-farm development in developing countries (II)—

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Summary An analysis of conventional on-farm development projects pointed out the lack of a systematic procedure applicable to implementation of the works. A new procedure has been developed by clarifying the requirements of each stage of the work from the field investigation to the construction and supervision stage. This procedure was characterized by: (1) adopting a grid survey map, (2) specifying the disposal of the soils, (3) estimating the earth-moving volume with the ponderable balancing method, (4) establishing criteria for quality control and (5) determining the scope of work of the supervisor.

For examining adaptability, the procedure was applied to an on-farm development project in Tanzania, which had the purpose of constructing 3,800 paddy fields with a dimension of 100×30 m.

On the basis of this application it was concluded that:
(1) a grid survey map was sufficient for designing on-farm works;
(2) rational disposal of the soil had a good effect on the growth of paddy;
(3) efficient design and the ponderable balancing method could exactly calculate the earth works;
(4) established criteria for quality control were justified by the smooth execution of the works and the easy farm operation; and
(5) the supervisor with conferred power could control the progress and the cost of the words.

I. Introduction

On-farm development works have been intensified in the 1980's in the frame of international cooperation. In spite of many engineers' efforts, however, the projects do not give satisfactory results compared with the targets which were anticipated in the project formulation. A study on some conventional projects showed that lack of a systematic procedure for on-farm works lowered the quality of the project.

In order to understand the problems pertaining to on-farm projects composed of many work items, a comparative study “before” and “after” construction of the
project was made. The results of the study showed the following bottlenecks: (1) preparing the detailed contour map, (2) execution of the earth works without sufficient pedological information, (3) precise and rapid evaluation of earth moving volume and (4) determining an appropriate procedure for construction and supervision.

For getting over these obstacles, a new procedure was developed after clarifying the requirements for on-farm works. The great emphasis in this process was placed on the technical transfer and adaptability to the developing countries, and the procedure was characterized by: (1) adopting a grid survey map, (2) specifying the disposal of the soils, (3) applying the “ponderable balancing method” to estimating the earth works, (4) establishing criteria for quality control and (5) strengthening the power of the supervisor.

This paper deals with an application of the developed procedure to a project and discussion of the results.

II. Application of the New Procedure to a Project

1. Purposes
Reports on conventional projects indicate that there are often disputes among the irrigation system designer, the client, the contractor and the farmer about the low efficiency of the constructed project. The causes of these disputes were not determined in detail, with the result that the personnel concerned hesitated to start similar projects elsewhere. For a further extension of on-farm projects, it is necessary to settle the scope of works of each staff involved in the project and the technical limits of the methods to be applied to the work.

The application to a real on-farm development project, therefore, has the objective of verifying the effectiveness and durability of the procedure and examining its adaptability to rice cultivation in a trial farm operation.

2. Work Flow of the Construction of the Farms and Construction Organization

Figure 1 shows the work flow surrounding the construction of the farms. Every stage indicated in the figure was performed and inspected in accordance with the procedure developed, which was formulated in form of contract documents.

Execution of the works requires at least three groups of personnel: (a) survey group, (b) construction group and (c) inspection group. Each group was organized by local field staff with the assistance of expatriate experts.

The survey group and the inspecting group are similar members in consisting of one skill surveyor, an assistant and four unskilled labourers recruited at the site. The construction group has two sub-groups: (a) a sub-group composed of operators of the construction equipment and (b) a subgroup for finishing work on the farm borders.

For accelerating the construction work, full use of heavy machinery was planned. The construction group used a 15-t ordinary bulldozer for both rough
levelling and the first levelling. The final levelling was executed with a 12-t motor grader. Embankment and compaction of the borders were done with the bulldozer. The construction equipment was imported and transported to the site, and the machines were operated by local staff under the supervision of expatriate experts. For standardizing ways to move the machines, the project set the reference points in the farm plot by trial operations. The construction operations were carried out from 1984 to 1987. The construction cost was about 20 million US$, financed by the Overseas Economic Cooperation Fund (OECF), Japan. Earth moving which
seriously affects the progress of the implementation, was scheduled to be suspended for 0.5 day in the case of rainfall of 10 to 30 mm, 1.0 day for 30 to 50 mm, and 2.0 days when rainfall exceeded 50 mm. The work days required for the on-farm development projects are estimated at 250 days.

3. **Main Features of the Project**

The procedure developed was applied to a project aiming at constructing paddy fields with an area of 1,100 ha and upland of 1,200 ha. The on-farm works were made vis-à-vis the paddy fields. The project was Lower Moshi Agricultural Development Project, which was located at the southern skirt of Mt. Kilimanjaro, about 5 to 20 km southeast of Moshi town, capital of the Kilimanjaro Region, the United Republic of Tanzania (see Figure 2). The project area extended along a gently sloping plain which was formed along a river. The land consists of fine textured alluvium, and the soils are primarily derived from clay to loamy alluvium. The soil material consists of about 35 to 50% clay and 30 to 40% silt fractions. The average slope was evaluated at 1/300.

The climate of the project area is the savanna type, characterized by three seasons, a rainy season (March to May), a dry season (June to October) and a short rain season (November to February), as Figure 3 shows. Seasonal flooding covers the project area from April to June.

**Figure 2** Location of the project area
Annual rainfall averages 705 mm, of which 442 mm falls in the rainy season, 74 mm in the dry season, and 160 mm in the short-rain season. Mean temperature is fairly constant throughout the year, being 21°C to 26°C. The average daily maximum temperature rises above 30°C from October to April, while daily minimum temperature falls close to 16°C in July and August.

The project aimed at constructing a headworks, an irrigation and drainage system, a farm road and a flood dike which protects the area from seasonal inundations. The area to be levelled was 1,100 ha, which is grouped into 42 irrigation
blocks as shown in Figure 4. Each irrigation block is demarcated by a secondary canal and a farm road. The irrigation block was divided into farm plots of 100×30 m. The total number of plots was about 3,800. Every farm plot was provided with a field ditch, a field drain, an access and a division box. The irrigation canals except for the field ditch were lined with concrete blocks because of scarce water resources. Water to irrigate the project area was taken from two rivers, and the project was designed to produce paddies.

Photo. 1 shows a general view of the project area before the start of the construction work.

Photo. 1 General view of the project area

III. Discussion

The suitability of the procedure was examined by site inspection, analysis of survey data, direct measurement of the completed works, evaluation of daily returns on the operation of construction equipment and trial planting of paddy.

1. Mapping

According to the contract documents, the project assigned one group to topographic survey. This group was composed of a local skilled surveyor, an unskilled assistant and five labourers; it made a grid survey with an interval of 20 m for the whole area. The survey work ended in 24 months, including time for clearance of the survey route. It costs about 120,000 US$, which is one-third the cost of aerial photographic mapping. Reading accuracy was 1 mm for the reference survey line and 1 cm for the grid point. Misreading was allowed up to ±5 mm, which was sufficient for evaluation of the earth works, as will be shown in section 3 below. System layout was set on a grid map, using an elevation interval of 50 cm. The designer could check and easily modify the layout by field investigations, if the surveyor failed to bring the required topographic data.

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2 Disposal of the Soil

Before construction began, the project area had been cultivated with maize in the upland and with paddy in the lowland areas. The cultivation was extensive, and test pitting in the area did not show the existence of a plough pan which separated the sub-soil from the surface soil rich in humus. Considering the importance of the soil containing organic matter, the project stripped the topsoil from an area with minimum depth of 10cm and a width of about 30 m along the projected embankment line and heaped it in the farm area. The stripped soil was sufficiently mixed with the sub-soil during the rough levelling with bulldozers, and a residual soil such as surplus of cut material for borders was spread over the farm through the final levelling by motor graders.

These methods of soil disposal contributed to a uniform growth of the paddy at the first cropping, as shown in Photo. 2.

![Photo. 2 Uniform growth of the paddy at the first cropping](image)

During the construction work, an unsuitably alkaline soil was found in a few blocks. The project experimentally studied the adaptability to both embankment material and structural base for the farm. The experiment showed that this soil could be easily washed out by rain, so it was considered useless for the embankment material. The soil, however, did not hinder the growth of paddy. The project, therefore, determined that removal of the soil from the farm was unnecessary. Any drain passing through an alkaline soil was protected with a concrete flume and a sod facing.

3. Accuracy in Designing

All the farms were constructed in accordance with drawings indicating the location and the design elevation. The elevation of the projected farm and the earth-moving volume were calculated with the ponderable balancing method. The exactness in computation was checked by comparing the calculated elevation with the executed one. The earth-moving volume was verified by the direct measure-
ment of the soils which were used for embankment of a canal, a road and borders, excavation of a drain and formation of the farm surface.

(1) **Variation in estimation of earth works due to a weighting coefficient more than 1.0** The number of survey points incorporated in a plot depends on the direction of the farm layout against the grid survey line. Figure 5 illustrates a typical farm layout. If the farm is leaning, the number of survey points in the plot is nearly constant. Figure 6 shows this case, in which one plot has survey points from 8 to 10, and there exists a peak at 8 points. If the farm is set out in parallel with the survey line, the survey points vary widely from one plot to another. Figure 7 shows one of the examples, which has two groups of distributed points. The first group stays at 5—6 and the second group at 10—12.

As the farm layout is systematically arranged after setting out the canal alignment, the designer encounters two cases of distribution of survey points. In the first case, he need not pay attention to an erroneous variation in estimating the earth-moving volume because of a negligible difference in distribution of survey points in a plot. In the second case, it is necessary to study whether the computa-

![Figure 5](image)

*Figure 5* Typical farm layout and distribution of survey points

![Figure 6](image)

*Figure 6* A sample distribution of survey points, if the farm is set at an inclination (Block No. 9)

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tion of earth works is affected by a disparity in the distribution of survey points.

The conventional way of weighting the area is to allot values of 1 or zero (2), or to calculate a coefficient proportioning to the calculating unit (3). The weighting coefficient, in any case, does not exceed 1.0.

When the farm layout is set out in parallel with the survey line and the plot is sectioned into calculating cells according to the developed method, many farms are provided with weighting coefficients greater than 1.

Figure 8 shows one example with a plot having a weighting coefficient over 1. Plot No. 206 was divided into five calculating cells. The hatched area indicated in 206 was a unit grid area equal to 400 m². If the designer paid attention to the survey points located within the plot, he counted 5 points. This meant that each point covered an area of over 400 m², resulting in allotting the weighting coefficient more than 1.

For making each weighting coefficient less than 1, the designer must take into consideration the influence of an adjacent survey point (hereinafter referred to as
an influential point) on the calculating cell. In this case, it was supposed that one survey point could never command over 400 m², and the surplus area was covered by a survey point staying in the neighbouring plot. A comparative study "with" and "without" the influential points was made.

This study was carried out with reference to the design elevation and the earth-moving volume.

The results for elevations are shown below.

<table>
<thead>
<tr>
<th>Block No.</th>
<th>Total plots of stand. dimensions</th>
<th>No. of 5- or 6-point plots</th>
<th>Difference in meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>73</td>
<td>19</td>
<td>-0.0026</td>
</tr>
<tr>
<td>23</td>
<td>55</td>
<td>21</td>
<td>+0.0019</td>
</tr>
<tr>
<td>27</td>
<td>57</td>
<td>24</td>
<td>0.0000</td>
</tr>
<tr>
<td>28</td>
<td>67</td>
<td>21</td>
<td>+0.0086</td>
</tr>
<tr>
<td>33</td>
<td>122</td>
<td>59</td>
<td>-0.0007</td>
</tr>
<tr>
<td>34</td>
<td>111</td>
<td>43</td>
<td>-0.0026</td>
</tr>
<tr>
<td>35</td>
<td>86</td>
<td>38</td>
<td>-0.0021</td>
</tr>
<tr>
<td>37</td>
<td>53</td>
<td>21</td>
<td>-0.0019</td>
</tr>
<tr>
<td>39</td>
<td>52</td>
<td>24</td>
<td>-0.0004</td>
</tr>
<tr>
<td>41</td>
<td>89</td>
<td>27</td>
<td>+0.0026</td>
</tr>
<tr>
<td>Total</td>
<td>765</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Even if the designer withdraws only 5-point and 6-point plots for a comparison, the evaluated difference is negligible. This difference will in fact be much smaller, since each block has many 10-point and 12-point plots which do not need the consideration of the influential points.

The results for earth-moving volume are given below.

<table>
<thead>
<tr>
<th>Block No.</th>
<th>Average difference in volume (m³/plot)*</th>
<th>Average difference in earth depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>-3.1</td>
<td>-0.001</td>
</tr>
<tr>
<td>23</td>
<td>-3.8</td>
<td>-0.001</td>
</tr>
<tr>
<td>27</td>
<td>+2.1</td>
<td>+0.001</td>
</tr>
<tr>
<td>28</td>
<td>-4.2</td>
<td>-0.001</td>
</tr>
<tr>
<td>33</td>
<td>-4.3</td>
<td>-0.001</td>
</tr>
<tr>
<td>34</td>
<td>-2.9</td>
<td>-0.001</td>
</tr>
<tr>
<td>35</td>
<td>-3.5</td>
<td>-0.001</td>
</tr>
<tr>
<td>37</td>
<td>-5.5</td>
<td>-0.002</td>
</tr>
<tr>
<td>39</td>
<td>-6.4</td>
<td>-0.002</td>
</tr>
<tr>
<td>41</td>
<td>-3.0</td>
<td>-0.001</td>
</tr>
</tbody>
</table>

Remark: The value of * marked was estimated using all standard plots in a block.

Average difference in earth depth for the plot ranges from -2 mm to +1 mm. If a reading error in level survey works is allowed to be ±5 mm, this difference must stay within the limits of tolerance.

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These comparative studies concluded that the earth works could be correctly calculated regardless of the magnitude of the weighting coefficient.

(2) Comparison between the designed and the executed earth-moving volumes

A comparative study between the designed and the executed elevations of the farm was made for examining the exactness of estimation by the ponderable balancing method. Figure 9 shows an example of the measurement of ground elevations before and after the construction of a farm. Although this block (Block No. 13) was constructed conforming to the drawing and there was a close relationship between the designed and the executed elevations, indicated by the equation $Y=0.97X+0.02$, some measured points were scattered around the theoretical line.

For clarifying the causes of this deviation, the project observed the earth-moving actually undertaken at the site. Figure 10 shows an example of earth-moving in

![Graph showing the relationship between designed and executed elevations.](image)

**Figure 9** An example showing a comparison between the designed and the executed elevations (Block No. 13)

<table>
<thead>
<tr>
<th>Block No.</th>
<th>Designed elevation (m)</th>
<th>Executed elevation (m)</th>
<th>Average difference (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2.76</td>
<td>2.74</td>
<td>0.02</td>
</tr>
<tr>
<td>8</td>
<td>2.17</td>
<td>2.12</td>
<td>0.05</td>
</tr>
<tr>
<td>9</td>
<td>1.95</td>
<td>1.91</td>
<td>0.04</td>
</tr>
<tr>
<td>10</td>
<td>2.77</td>
<td>2.72</td>
<td>0.05</td>
</tr>
<tr>
<td>12</td>
<td>1.49</td>
<td>1.42</td>
<td>0.07</td>
</tr>
<tr>
<td>13</td>
<td>1.82</td>
<td>1.78</td>
<td>0.04</td>
</tr>
<tr>
<td>14</td>
<td>2.96</td>
<td>2.88</td>
<td>0.08</td>
</tr>
<tr>
<td>15</td>
<td>1.76</td>
<td>1.68</td>
<td>0.08</td>
</tr>
<tr>
<td>16</td>
<td>1.49</td>
<td>1.47</td>
<td>0.02</td>
</tr>
</tbody>
</table>

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Block No. 13. On the basis of the ponderable balancing method the designer balanced the cut and filled within the plot. The soils, however, were moved outside the plot in a real earth-moving operation. This violation of the contract documents had the purpose of avoiding an obstructive area and obtaining the most efficient operation of the construction equipment.

These observations suggest that the computation accuracy of the method must be examined using the total earth moving volumes within a block, not within a plot.

Table 1 shows the differences between the average designed and the executed elevations of the block. Averaging the differences in elevation from Block No. 7 to Block No. 16 indicates that the executed elevation is always 5cm/plot below the designed one.

This discrepancy was studied by measuring the embankment volumes, which were subtracted a priori from the calculation of the land levelling works.

Direct measurement of the soils used as embankment material was applied to the farms in Block No. 10 and No. 13, with the following results.

<table>
<thead>
<tr>
<th>Embankment volumes</th>
<th>Example 1</th>
<th>Example 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Borders between farms</td>
<td>66</td>
<td>60</td>
</tr>
<tr>
<td>2. Border between the farm and the field drain</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>3. Field ditch and farm road</td>
<td>135</td>
<td>121</td>
</tr>
<tr>
<td>Total</td>
<td>220</td>
<td>196</td>
</tr>
</tbody>
</table>

An excavation of the field drain running along the farm gave an amount of soil which could be used for the embankment. This volume was evaluated at 19 m$^3$.
and the deduction of this volume from the above embankment volume enabled us to estimate a net embankment volume which was really collected from the farm area using construction equipment.

The design embankment volume was calculated using the standard transverse sections of the field ditch and the farm road typically set out on the drawing. This volume was evaluated at 45 m³ for one plot.

The summation of the above values showed a net surplus embankment volume of 156 m³ and 132 m³, corresponding to a soil depth of 5.2 cm and 4.4 cm respectively.

Study of the discrepancy between the designed and the executed elevations concluded that the ponderable balancing method precisely estimated the earth-moving volume, but the operation of construction equipment excavated and moved the soil in an excessive manner for the following reasons.
(a) The contract prohibited the installation of a canal smaller than the designed one; the operator, therefore, tried to construct an over-sized canal.
(b) The contract ordered that the irrigation and drainage systems be maintained for one year after the construction; for minimizing the laborious procedures which were required for repairing the field ditch, its lateral embankment was made thicker than the designed one.
(c) Although the contract ordered the compaction of borders under conditions of optimum soil moisture, water was not introduced into the farmland in order that smooth operation of the construction equipment not be hindered; the operator carried out surplus embankment, being afraid of the structural fragility of the border.
(d) The excavated soil obtained from the field drain was not sufficiently used for construction of the farm road, the field ditch and the farm.
(e) Although the contract specified that the road had to be constructed with a constant thickness of embankment regardless of the undulation of the land, the operator smoothed the road by filling up the depressed places after collecting surplus soil from the farm area.
(f) The staking interval of 20 m was not sufficient for collecting all the data on micro relief of the project area.

4. Quality of the Executed Works
Defective construction makes a complete design come to nothing. Constructed farms were checked for the flatness of the ground surface and the slope. In addition, the project studied the training effect on the quality of the works.

(1) Flatness The survey points distributed in a plot were statistically analysed according to the procedure developed in part (1) of this paper. The maximum number of points was 10. The flatness of the surface was checked alloting 10 survey points with a rectangular mesh to each farm.

Figure 11 shows a distribution of the points which were most deviated from the average surface elevation of the farm. Farms totalling 1,600 points stayed within the tolerance of ±7.5 cm; the peak was found at 5.3cm, with a standard
deviation of 1.3 cm.

(2) Slopes of the farm  The slope which is to be discussed here is an inclination of the ground surface from the field ditch to the field drain. The contract documents gave no specifications about the slope of the farm. To predict the irrigability of the farm after construction, the project studied the slope using a statistical method.

The deviation was calculated by averaging the elevation of two survey points located either on the field ditch side or on the field drain side. **Figure 12** shows an example where this block contains many farms running down with a gentle slope from the field ditch to the field drain. **Figure 13** shows an example of the opposite case. This analysis was applied to 22 blocks, of which 17 blocks were characterized by an inclination from the field ditch to the field drain. The remaining 5 blocks had an inverse slope, and introducing the water into these blocks caused little difficulty. This difficulty was surmounted by constructing a tentative ridge allowing water to be supplied from the field drain side.

(3) Training effect on the quality of the work  Although the flatness of the constructed farms indicated that the local operators were sufficiently skilled, a comparative study was undertaken to evaluate the effect of training.

**Table 2** shows improvement in operation for 6 months from the beginning of
levelling. The quality of the work is almost constant for the group composed of expatriate operators and it is improved for the group of local operators trained and educated by an expatriate expert.

A trial operation of the construction equipment was envisaged for studying whether well-trained local operators could contribute to improving the flatness of the farms. Using Block No. 31, the motor grader for final levelling was operated twice as long, while the bulldozer was moved for the same number of operating
Table 2  Comparison between expatriate operators and local operators

<table>
<thead>
<tr>
<th>(A) Expatriate group</th>
<th>Block No.</th>
<th>Average deviation (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order of construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5.8</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>6.2</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>3.8</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>5.6</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Remark: Expatriate operators directly moved the construction equipment.

<table>
<thead>
<tr>
<th>(B) Local group</th>
<th>Block No.</th>
<th>Average deviation (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order of construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>18</td>
<td>5.4</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>5.3</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>5.3</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>5.2</td>
</tr>
<tr>
<td>6</td>
<td>16</td>
<td>4.8</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>5.3</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>4.8</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>5.0</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Remark: Trained local operators moved the construction equipment.

Figure 14  Improved flatness with prolonged operation hours (Block No. 31)

hours. Figure 14 shows the results where the total average deviation is 2.9 cm with a standard deviation of 1.0 cm. A remarkable improvement in flatness was confirmed.
5. **Supervision of Construction Progress**

The performance of the works was checked for progress and cost.

**1) Progress control** A detailed list of construction equipment and a work schedule were devised for completing the construction of about 3,800 plots within 3 years.

The list submitted by the contractor indicated that the final levelling would be done by bulldozers. As land planing by bulldozer required a skilled operator unavailable in the country, it was proposed to use a motor grader for finishing. In alternative studies on selection of machines, the use of specific equipment such as a land planer was omitted for purposes of reducing the expenditure.

One group of construction equipment was composed of a 15-t ordinary bulldozer and a 12-t motor grader. The group completed 1.5 plot/day at the beginning of the work and about 4 plots/day at full stage of construction. The work was successfully finished by two operating groups and one extra group.

**2) Cost control** As earth-moving works account for from 40% to 50% of the cost of on-farm works, it is not too much to say that the scale of a project is determined by the cost allotted to the land levelling works.

An on-farm development project in a developing country costs from 1/2 to 1/3 of what one costs in Japan. Land levelling cost in Japan ranges from 6,000 to 8,000 US$/ha. Therefore, the unit amount ranging from 2,000 to 2,700 US$/ha is considered a reasonable price for land levelling in a developing country.

The project area had an average slope of 1/300, and the soil moved amounted to 250 m³/plot. With this moving volume and construction efficiency, the levelling cost was calculated. It did not exceed 2,000 US$/ha.

6. **Evaluation of the Project by a Trial Farm Operation**

An on-farm development project envisaged in a developing country is required to yield maximum products soon after the completion of the work. The project is commonly scheduled to increase the yield by improving and repairing the farm for the first 4 years and to attain the full stage in the fifth year after construction.

The most serious problems occur in the first cropping, and all the problems at this stage are discovered not by the personnel involved in the project construction but by the farmers.

The following section deals with some problems in the first cropping, which belong to the technical matters involved in the project.

**1) Irrigability** As they were not allowed to prepare a nursery bed on each individual farm, the farmers used about 4% of the block as a communal nursery bed. On preparing the nursery bed, they complained to the project that they could not uniformly irrigate the communal nursery because of the undulation of the surface.

This communal nursery bed was prepared in the following steps; (1) introducing water into the farm; (2) puddling by a tractor mounted with a rotary tiller; (3) collecting and heaping the water-saturated soil with a hoe in the ponding water; (4) final levelling and (5) sowing on the land.
This method has the following inconveniences:

(a) insufficient height of the nursery bed weakens the seedlings;
(b) adjustment of the water depth in the communal nursery bed is difficult; and
(c) excess water is evacuated by cutting the border, resulting in washing out the surface soil.

The complaint of the farmers on this matter was dealt with by modifying the preparation method of the nursery bed as shown below.

Step 1: introduce a large amount of water onto the farm and leave it stagnating;
Step 2: after confirming the disappearance of surface water, collect and heap the softened soil by a hoe to a height from 20 to 30cm in the shape of a bed;
Step 3: introduce water onto the farm once more;
Step 4: remove the surplus soil and throw it into the water by a hoe in a manner that the surface of the nursery bed is located between 8cm and 10cm above the water surface and
Step 5: sow on the farm.

(2) Discrepancy in height between the cut and the fill areas  Surplus fill was omitted from the estimation of the earth-moving volume. Some farmers complained about the discrepancy in height within a plot. A field investigation pointed out that this discrepancy was caused by an insufficiency of fill. There seem to be two methods for overcoming this difficulty. The first is to move and heap surplus soil in the fill area, resulting in a steep increase in the cost of demarcating the area. The second is to plough the land deeply and mix the surface soil with the subsoil before the levelling. Although the second method is simple, it does not necessarily have a good effect on the growth of the crop. It must be tested by a trial cultivation.

The boundary between the cut and the fill areas disappears with the repetition of puddling. At the first cropping, the farm can be irrigated by installing a tentative ridge on the boundary.

VI. Conclusion

A study on the conventional projects pointed out some problems with the on-farm words. After clarifying the requirements for each component of the work, a systematic procedure applicable to the investigation, the design and the construction and supervision was developed and applied to a real construction project after standardization of the said procedure. The conclusions of this application can be summarized as follows.

1. Mapping was accomplished by the local staff without any delay in the progress of the construction work. Survey costs were low and the accuracy of the maps was sufficient for designing on-farm works.
2. The disposal of soils raised the quality of the embankment materials and assured uniform growth of the paddy.
3. Design work was smoothly executed. The ponderable balancing method could precisely estimate the earth works, and could be mastered by the local field staff.

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without any difficulty.

4. A rational training of unskilled local operators enabled them to grade the land to a level within a tolerance range of ±7.5 cm. This range was justified by easy and sure farm operation.

5. The works were completed within the projected period. The land levelling for 3,800 plots, in particular, was finished by two operating groups and an extra group, using a bulldozer and a motor grader.

6. Construction costs for on-farm works stayed within the anticipated ranges.

7. Actual farm operation showed that the project yield of paddy rice was 7.5 t/ha/crop at the first cropping, which was 60% more than the amount projected at the full stage.

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