IN the past decades, the world's food production was mostly practiced by a monoculture system, i.e., growing only one crop over an area. The monoculture causes damages (in changes) to the biological diversity, especially soil fertility. The sustainable agriculture is an approach of managing crop ecology in order to maintain the biological diversity, productivity, and long-term human existence. One methodology of sustainable agriculture is called Intercropping, i.e., multiple crops are planted in the same area. In the intercropping planning, many cultivating factors, such as diseases, sale prices and cultivating areas, must be concerned because those factors are affected to ecological succession and total income of production. Producers have to face with the complication of many factors in order to obtain the optimal plan under the concept of sustainable agriculture. This paper proposes an expert system model for intercropping planning. The model analysis and design were exhaustively discussed in terms of ecology as an agricultural expert, benefit as an economist and system analysis and design as an information technologist. This model has been proved to provide the efficient and practical intercropping plans.

System Framework

Intercropping Planning System

Method

Linear Programming

Process

Intercrop Group Discovery

Model Construction

User Preferences

Core Database

Model Evaluation

Vegetable database

An example of diseases in Kale and Long Bean

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Kale</th>
<th>Long Bean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fungi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Peronospora parasitica (damping-off, leaves and heads)</td>
<td>1. Cercospora capsici (red spot)</td>
<td>2. Colletotrichum lindenmuthianum (anthracnose)</td>
</tr>
<tr>
<td>2. Pythium ultimum (damping-off)</td>
<td>3. Erysiphe polygoni (powdery mildew)</td>
<td>4. Uromyces vignae (rust)</td>
</tr>
<tr>
<td>Bacteria</td>
<td>1. Pseudomonas</td>
<td></td>
</tr>
<tr>
<td>Viruses</td>
<td>1. Cauliflower mosaic virus (CaMV)</td>
<td></td>
</tr>
<tr>
<td>2. Turnip mosaic virus (TuMV)</td>
<td>2. Cucumber mosaic virus (Cucumber)</td>
<td></td>
</tr>
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</table>

An example of data for planning calculations.

<table>
<thead>
<tr>
<th>Database</th>
<th>Kale</th>
<th>Long Bean</th>
<th>Tomato</th>
</tr>
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<tbody>
<tr>
<td>Sale price per plant (Baht), si</td>
<td>2.63</td>
<td>0.37</td>
<td>1.26</td>
</tr>
<tr>
<td>Periods of growing until harvesting (Day), di</td>
<td>85.5</td>
<td>50</td>
<td>133</td>
</tr>
<tr>
<td>Cultivating area per plant (Square meters), ai</td>
<td>0.09</td>
<td>0.02</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Identification numbers (ID) and names of all vegetables used in the discovery process

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cauliflower</td>
</tr>
<tr>
<td>2</td>
<td>Cabbage</td>
</tr>
<tr>
<td>3</td>
<td>Cabbage</td>
</tr>
<tr>
<td>4</td>
<td>Onion</td>
</tr>
<tr>
<td>5</td>
<td>Welsh Onion</td>
</tr>
<tr>
<td>6</td>
<td>Cucumber</td>
</tr>
<tr>
<td>7</td>
<td>Long Bean</td>
</tr>
<tr>
<td>8</td>
<td>Chinese Cabbage</td>
</tr>
<tr>
<td>9</td>
<td>Hom Lettuce</td>
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Vegetable database

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<th>Disease</th>
<th>ID</th>
<th>Name</th>
</tr>
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<tbody>
<tr>
<td>Kale</td>
<td>10</td>
<td>Kale</td>
</tr>
<tr>
<td>Cabbage</td>
<td>11</td>
<td>Cabbage</td>
</tr>
<tr>
<td>Cabbage</td>
<td>12</td>
<td>Cabbage</td>
</tr>
<tr>
<td>Onion</td>
<td>13</td>
<td>Onion</td>
</tr>
<tr>
<td>Welsh Onion</td>
<td>14</td>
<td>Welsh Onion</td>
</tr>
<tr>
<td>Cucumber</td>
<td>15</td>
<td>Cucumber</td>
</tr>
<tr>
<td>Long Beam</td>
<td>16</td>
<td>Long Beam</td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>17</td>
<td>Chinese Cabbage</td>
</tr>
<tr>
<td>Hom Lettuce</td>
<td>18</td>
<td>Hom Lettuce</td>
</tr>
</tbody>
</table>

Intercrop Group Discovery

All diseases of several vegetables related with Kale.

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Vegetable IDs</th>
<th>Vegetable Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fungal</td>
<td>1,2,3,4,5,6,7</td>
<td>Kale, Long bean</td>
</tr>
<tr>
<td>Bacterial</td>
<td>10,11,12,13,14,15,16,17,18</td>
<td>Coriander and Tomato</td>
</tr>
<tr>
<td>Vascular</td>
<td>19,20,21,22,23,24,25,26,27,28,29,30</td>
<td>Kale and Bird chili</td>
</tr>
<tr>
<td>Viral</td>
<td>31,32,33,34,35,36,37,38,39,40,41,42</td>
<td>Kale and Capsicum</td>
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</tbody>
</table>

Model construction process

Weight derivation from all the factors

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Results of weight derivation from all the factors.

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<thead>
<tr>
<th>Disease</th>
<th>Plant Kinetics</th>
<th>Kale</th>
<th>Long Bean</th>
<th>Tomato</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kale</td>
<td>0</td>
<td>235.96</td>
<td>471.32</td>
<td>707.88</td>
</tr>
<tr>
<td>Long Bean</td>
<td>0</td>
<td>56.77</td>
<td>113.53</td>
<td>170.88</td>
</tr>
<tr>
<td>Tomato</td>
<td>0</td>
<td>107.33</td>
<td>214.65</td>
<td>321.83</td>
</tr>
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</table>

Model Evaluation

Results of allocated areas of each vegetable and total income.

<table>
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This paper proposes an expert system model for intercropping planning in order to maximize income while minimize the economic risk. The model analysis and design were exhaustively discussed in terms of ecology as an agricultural expert, benefit as an economist and system analysis and design as an information technologist. All cultivating factors have been investigated and applied to construct the proposed model. The model was evaluated by comparing with a linear programming method. The experimental results revealed that the linear programming method provides the highest income, but it could not accomplish in the risk minimization. On the other hand, this proposed model could minimize the risk and also obtained at least 74% when compared with the linear programming method.