Soil Cultivation and Land Use

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Soil Cultivation and Land Use
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# Tartalom

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Environmental factors determining soil fertility and field crop yield</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>Light</td>
<td>2</td>
</tr>
<tr>
<td>1.3</td>
<td>Air temperature</td>
<td>3</td>
</tr>
<tr>
<td>1.4</td>
<td>Wind</td>
<td>5</td>
</tr>
<tr>
<td>1.5</td>
<td>Precipitation</td>
<td>5</td>
</tr>
<tr>
<td>1.6</td>
<td>Hydrological factors</td>
<td>7</td>
</tr>
<tr>
<td>2.1</td>
<td>Methods of influencing the water, heat and air management of soils</td>
<td>10</td>
</tr>
<tr>
<td>2.2</td>
<td>Water management of the soil</td>
<td>10</td>
</tr>
<tr>
<td>2.3</td>
<td>Heat management of the soil</td>
<td>14</td>
</tr>
<tr>
<td>3.1</td>
<td>Environmental factors determining soil fertility and field crop yield</td>
<td>17</td>
</tr>
<tr>
<td>3.2</td>
<td>SOIL TILLAGE SYSTEMS OF FIELD CROPS</td>
<td>17</td>
</tr>
<tr>
<td>3.3</td>
<td>Tillage systems categorised by sowing date</td>
<td>26</td>
</tr>
<tr>
<td>3.4</td>
<td>Tillage systems for late summer and autumn sown crops</td>
<td>26</td>
</tr>
<tr>
<td>3.5</td>
<td>Tillage systems for spring sown crops</td>
<td>26</td>
</tr>
<tr>
<td>3.6</td>
<td>Tillage systems for secondary crop</td>
<td>26</td>
</tr>
<tr>
<td>3.7</td>
<td>Cultivation methods of different soil types</td>
<td>26</td>
</tr>
<tr>
<td>3.8</td>
<td>Characteristics of brown forest soil affecting soil cultivation</td>
<td>27</td>
</tr>
<tr>
<td>3.9</td>
<td>Guidelines for cultivation of brown forest soils</td>
<td>28</td>
</tr>
<tr>
<td>3.10</td>
<td>Chernozem soils</td>
<td>30</td>
</tr>
<tr>
<td>3.11</td>
<td>Characteristics of chernozem soils affecting cultivation</td>
<td>30</td>
</tr>
<tr>
<td>3.12</td>
<td>Guidelines for chernozem soil cultivation</td>
<td>31</td>
</tr>
<tr>
<td>3.13</td>
<td>Meadow soils</td>
<td>32</td>
</tr>
<tr>
<td>3.14</td>
<td>Characteristics affecting the cultivation of heavy meadow soil</td>
<td>33</td>
</tr>
<tr>
<td>3.15</td>
<td>Guidelines of the cultivation of heavy meadow soils</td>
<td>34</td>
</tr>
<tr>
<td>3.16</td>
<td>Alkaline soils</td>
<td>35</td>
</tr>
<tr>
<td>3.17</td>
<td>Characteristics of alkaline soils affecting cultivation</td>
<td>35</td>
</tr>
<tr>
<td>3.18</td>
<td>Guidelines for soil cultivation of alkaline soils</td>
<td>37</td>
</tr>
<tr>
<td>3.19</td>
<td>Sandy (skeletal) soils</td>
<td>37</td>
</tr>
<tr>
<td>3.20</td>
<td>Soil characteristics of sandy soils affecting cultivation</td>
<td>37</td>
</tr>
<tr>
<td>3.21</td>
<td>Guidelines for soil cultivation of sandy soils</td>
<td>38</td>
</tr>
<tr>
<td>3.22</td>
<td>Marsh soils</td>
<td>40</td>
</tr>
<tr>
<td>3.23</td>
<td>Characteristics affecting the cultivation of the marsh soils</td>
<td>40</td>
</tr>
<tr>
<td>3.24</td>
<td>Guidelines for soil cultivation of marsh soils</td>
<td>40</td>
</tr>
<tr>
<td>3.25</td>
<td>Conservation tillage systems</td>
<td>41</td>
</tr>
<tr>
<td>3.26</td>
<td>Characteristics of conventional tillage systems</td>
<td>41</td>
</tr>
<tr>
<td>3.27</td>
<td>Characteristics of minimum tillage system</td>
<td>42</td>
</tr>
<tr>
<td>3.28</td>
<td>Characteristics of reduced tillage system</td>
<td>42</td>
</tr>
<tr>
<td>3.29</td>
<td>Characteristics of conservation tillage systems</td>
<td>42</td>
</tr>
<tr>
<td>3.30</td>
<td>No-tillage or direct seeding</td>
<td>43</td>
</tr>
<tr>
<td>3.31</td>
<td>Slot-planting</td>
<td>44</td>
</tr>
<tr>
<td>3.32</td>
<td>Strip-tillage</td>
<td>44</td>
</tr>
<tr>
<td>3.33</td>
<td>Ridge-tillage</td>
<td>46</td>
</tr>
<tr>
<td>3.34</td>
<td>Mulch tillage</td>
<td>47</td>
</tr>
<tr>
<td>3.35</td>
<td>Western Europe type tillage systems</td>
<td>48</td>
</tr>
<tr>
<td>3.36</td>
<td>Tillage systems comparisons</td>
<td>48</td>
</tr>
<tr>
<td>3.37</td>
<td>The necessity, method and tools of deep tillage</td>
<td>50</td>
</tr>
<tr>
<td>3.38</td>
<td>Cause and significance of soil compaction</td>
<td>50</td>
</tr>
<tr>
<td>3.39</td>
<td>Factors influencing soil compaction</td>
<td>52</td>
</tr>
<tr>
<td>Page</td>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>81</td>
<td>4.3.9.4.3</td>
<td>Based on the adjustment of the solution concentration</td>
</tr>
<tr>
<td>81</td>
<td>4.4.9.4.4</td>
<td>Based on plant analysis</td>
</tr>
<tr>
<td>82</td>
<td>4.5.9.4.5</td>
<td>The nitrogen minimum method</td>
</tr>
<tr>
<td>82</td>
<td>4.6.9.4.6</td>
<td>Using yield simulation models</td>
</tr>
<tr>
<td>82</td>
<td>4.6.1.9.4.6.1</td>
<td>Empirical models</td>
</tr>
<tr>
<td>82</td>
<td>4.6.2.9.4.6.2</td>
<td>Dynamic yield simulation models</td>
</tr>
<tr>
<td>82</td>
<td>4.6.3.9.4.6.3</td>
<td>Decision preparation systems</td>
</tr>
<tr>
<td>83</td>
<td>5.9.5</td>
<td>Nutrient supply of organic farming</td>
</tr>
<tr>
<td>83</td>
<td>6.9.6</td>
<td>Calculation of the amount of fertiliser active ingredient</td>
</tr>
<tr>
<td>83</td>
<td>7.9.7</td>
<td>Environmental aspects of nutrient supply</td>
</tr>
<tr>
<td>85</td>
<td>8.9.8</td>
<td>Precision, production site-specific fertilisation</td>
</tr>
<tr>
<td>85</td>
<td>8.1.9.8.1</td>
<td>Precision collection of soil data</td>
</tr>
<tr>
<td>85</td>
<td>8.2.9.8.2</td>
<td>Production site-specific fertilisation</td>
</tr>
<tr>
<td>87</td>
<td>10.10.1</td>
<td>The importance of production site and soil protection</td>
</tr>
<tr>
<td>89</td>
<td>10.10.2</td>
<td>Land consolidation</td>
</tr>
<tr>
<td>90</td>
<td>10.10.3</td>
<td>Plot development</td>
</tr>
<tr>
<td>90</td>
<td>10.10.3.1</td>
<td>Guidelines of plot development</td>
</tr>
<tr>
<td>90</td>
<td>10.10.3.2</td>
<td>Guidelines of plot development on slopes</td>
</tr>
<tr>
<td>92</td>
<td>10.10.4</td>
<td>Development and forms of erosion</td>
</tr>
<tr>
<td>92</td>
<td>10.10.4.2</td>
<td>Alternatives of protection against erosion</td>
</tr>
<tr>
<td>97</td>
<td>10.10.5</td>
<td>Deflation</td>
</tr>
<tr>
<td>97</td>
<td>10.10.5.1</td>
<td>Factors eliciting and affecting deflation</td>
</tr>
<tr>
<td>98</td>
<td>10.10.5.2</td>
<td>Protection against deflation</td>
</tr>
<tr>
<td>102</td>
<td>11.11.1</td>
<td>Concept and tasks of soil improvement</td>
</tr>
<tr>
<td>102</td>
<td>11.11.2</td>
<td>Improvement of saline soils</td>
</tr>
<tr>
<td>102</td>
<td>11.11.2.1</td>
<td>Types of saline soils</td>
</tr>
<tr>
<td>103</td>
<td>11.11.2.2</td>
<td>Improvement of saline soils</td>
</tr>
<tr>
<td>104</td>
<td>11.11.3</td>
<td>Improvement of acidic soils</td>
</tr>
<tr>
<td>105</td>
<td>11.11.3.1</td>
<td>Reasons for soil acidification</td>
</tr>
<tr>
<td>105</td>
<td>11.11.3.2</td>
<td>Methods of improving acidic soils</td>
</tr>
<tr>
<td>105</td>
<td>11.11.3.3</td>
<td>Determining the liming dose</td>
</tr>
<tr>
<td>106</td>
<td>11.11.3.4</td>
<td>Substances used for the improvement of acidic soils</td>
</tr>
<tr>
<td>107</td>
<td>11.11.3.5</td>
<td>Implementation of meliorative liming</td>
</tr>
<tr>
<td>107</td>
<td>11.11.4</td>
<td>Improvement of sandy soils</td>
</tr>
<tr>
<td>107</td>
<td>11.11.4.1</td>
<td>Mechanical improvement of sandy soils</td>
</tr>
<tr>
<td>108</td>
<td>11.11.4.2</td>
<td>Other methods of improving sandy soils</td>
</tr>
<tr>
<td>109</td>
<td>11.11.5</td>
<td>Improvement of the physical and biological soil condition</td>
</tr>
<tr>
<td>109</td>
<td>11.11.5.1</td>
<td>Reducing soil disturbance</td>
</tr>
<tr>
<td>109</td>
<td>11.11.5.2</td>
<td>Development and maintenance of the loose soil layer close to the surface</td>
</tr>
<tr>
<td>112</td>
<td>12.12</td>
<td>Land use systems</td>
</tr>
<tr>
<td>112</td>
<td>12.12.1.1</td>
<td>The basis of distinguishing land use systems</td>
</tr>
<tr>
<td>112</td>
<td>12.12.1.2</td>
<td>Constituents of land use systems</td>
</tr>
<tr>
<td>113</td>
<td>12.12.2</td>
<td>Land use system types</td>
</tr>
<tr>
<td>114</td>
<td>12.12.2.1</td>
<td>Uncultivated, pasture and forest switching tillage system</td>
</tr>
<tr>
<td>114</td>
<td>12.12.2.2</td>
<td>Fallowland use system</td>
</tr>
<tr>
<td>115</td>
<td>12.12.2.3</td>
<td>Crop rotation land use system</td>
</tr>
<tr>
<td>116</td>
<td>12.12.2.4</td>
<td>Development of the Norfolk crop rotation system</td>
</tr>
<tr>
<td>116</td>
<td>12.12.2.5</td>
<td>Ley land use system</td>
</tr>
<tr>
<td>116</td>
<td>12.12.2.6</td>
<td>Free land use system</td>
</tr>
<tr>
<td>117</td>
<td>12.12.2.7</td>
<td>Monoculture land use system</td>
</tr>
<tr>
<td>117</td>
<td>12.12.2.8</td>
<td>Current land use systems</td>
</tr>
<tr>
<td>120</td>
<td>13.13</td>
<td>Irrigation farming</td>
</tr>
<tr>
<td>120</td>
<td>13.13.1</td>
<td>The impact of irrigation on the soil</td>
</tr>
<tr>
<td>121</td>
<td>13.13.2</td>
<td>Tillage of irrigated soils</td>
</tr>
<tr>
<td>124</td>
<td>14.14</td>
<td>The natural regions of Hungary</td>
</tr>
<tr>
<td>124</td>
<td>14.14.1</td>
<td>List of Hungary’s natural regions</td>
</tr>
</tbody>
</table>
Soil Cultivation and Land Use

2. 14.2. Danube plain ................................................................. 125
   2.1. 14.2.1 Description of the Danube flatland ................................ 125
   2.2. 14.2.2 Description of the Danube-Tisza mid-region flatland .......... 126
   2.3. 14.2.3 Description of the Bacska ridge ................................ 126
   2.4. 14.2.4 Description of the Mezőöld .................................... 126
   2.5. 14.2.5 Description of the Dráva flatland .............................. 126

3. 14.3 Tisza Plain ................................................................. 126
   3.1. 14.3.1 Description of the Upper Tisza region .......................... 127
   3.2. 14.3.2 Description of the Central Tisza region ...................... 127
   3.3. 14.3.3 Description of the Lower Tisza region ....................... 127
   3.4. 14.3.4 Description of the North Great Plain alluvial cone flatland . 128
   3.5. 14.3.5 Description of Nyírség ........................................ 128
   3.6. 14.3.6 Description of Hajdúság ....................................... 128
   3.7. 14.3.7 Description of the Berettyő-Körös region .................... 128
   3.8. 14.3.8 Description of the Körös-Maros mid-region .................. 129

4. 14.4 Little Plain ............................................................... 129
   4.1. 14.4.1 Description of the Győr basin .................................. 129
   4.2. 14.4.2 Description of the Marcal basin .............................. 129
   4.3. 14.4.3 Description of the Komárom-Esztergom flatland ............. 129

5. 14.5 Western Hungarian periphery region ................................. 130
   5.1. 14.5.1 Description of the Feet of the Alps ............................ 130
   5.2. 14.5.2 Description of the Sopron-Vas flatland ...................... 130
   5.3. 14.5.3 Description of the Kemenes Ridge ............................. 130
   5.4. 14.5.4 Description of the Zala hills ................................ 130

6. 14.6 Transdanubian hill country ............................................ 131
   6.1. 14.6.1 Description of Outer Somogy .................................. 131
   6.2. 14.6.2 Description of Inner Somogy ................................... 131
   6.3. 14.6.3 Description of the Tolna-Baranya hill country .............. 131
   6.4. 14.6.4 Description of the Mecsek and Mórágy hills ................ 132

7. 14.7 Transdanubian Mid-Mountains ......................................... 132
   7.1. 14.7.1 Description of the Bakony region ............................. 132
   7.2. 14.7.2 Description of the Vértes-Velence highlands and its region . 132
   7.3. 14.7.3 Description of the Dunazug highlands ........................ 132

8. 14.8 Northern Hungary Mid-Mountains ..................................... 133
   8.1. 14.8.1 Description of the Danube bend highlands and the Nógrád basin . 133
   8.2. 14.8.2 Description of the Cserhát region ............................ 133
   8.3. 14.8.3 Description of the Mátra region .............................. 133
   8.4. 14.8.4 Description of the Bükk region .............................. 134
   8.5. 14.8.5 Description of the Heves-Borsod basins and hill countries . 134
   8.6. 14.8.6 Description of the North Borsod highlands .................. 134
   8.7. 14.8.7 Description of the Tokaj-Zemplén highlands ................. 134

15. 15. The basic elements of regional production. Correlation between regional varieties, biological based and production technologies .................................................. 135
   1. 15.1 The concept of region and its role in farming ..................... 135
   2. 15.2 Aspects of environmental friendly farming ........................ 135
   3. 15.3 Aspects influencing the sustainability and adaptability of crop production ......................................................... 136
   4. 15.4 Main areas of adapting to a region ................................ 137
   4.1. 15.4.1 Sowing structure, crop variety structure ..................... 137
       4.1.1. 15.4.1.1 Aboriginal and indigenous cash crops ................. 137
       4.1.2. 15.4.1.2 Concept of regional variety, reasons for its existence . 137
       4.1.3. 15.4.1.3 Alternatives of preserving regional varieties ........ 138
       4.1.4. 15.4.1.4 Significance of breeding regional varieties ........ 138
   5. 15.5 Crop rotation adapted to regional farming ........................ 138
   6. 15.6 Vegetable structure adapting to the region ........................ 139
   7. 15.7 Cultivation adapted to the region .................................. 139
   8. 15.8 Soil conservancy and fertilisation adapted to the region ........ 139
   9. 15.9 Environmental protection adapted to the region ................. 140
   10. 15.10 Necessity and possibility of the improvement of the correlation system between crop production and the region ......................................................... 141
   11. 15.11 Requirements of the future agricultural farms .................. 141
16. Questions: ............................................................................................................ 143
17. Bibliography ......................................................................................................... 146
Az ábrák listája
1.1. Figure 1. Values of the solar invariant, extra-terrestrial radiation (ETR) and global radiation (GRAD) in Debrecen ............................................................... 3
1.2. Figure 2. Average yearly precipitation (Debrecen, 1989-2008) ......................................................... 7
1.3. Figure 3. Elements of soil water balance .......................................................... 8
2.1. Figure 4. Wetting soil moisture profiles ................................................................. 10
2.2. Figure 5. pH curves of sandy, adobe and clay soils .................................................... 12
2.3. Figure 6. The effect of cultivation on the moisture content of the soil under various weather circumstances in adobe soil ................................................................................. 13
2.4. Figure 7. Heat capacity of chernozem soils against moisture content and soil looseness ........... 15
2.5. Figure 8. Temperature conduction ability of chernozem soils against moisture content and soil looseness .................................................................................................................................................... 15
3.1. Figure 9. Stubble-stripping ................................................................................. 18
3.2. Figure 10. Equipment of the primary tillage .............................................................. 19
3.3. Figure 11. Loosening, crumbling and compaction work of the combinatory ................. 20
3.4. Figure 12. Seedbed preparation shortcomings ............................................................... 20
3.5. Table 1. Field crops’ need for small crumbled soil structure in the seedbed ..................... 20
3.6. Figure 13. Tillage systems of late summer and autumn sown plants after previous crops with short growing season ........................................................................................................... 21
3.7. Figure 14. Tillage systems of late summer and autumn sown plants after previous crops with long growing season ........................................................................................................ 22
3.8. Figure 15. Tillage systems of spring sown plants after previous crops with short growing season 24
3.9. Figure 16. Tillage systems of spring sown plants after previous crops with long growing season 25
4.1. Figure 17. Situation of main soil types in Hungary ...................................................... 26
4.2. Figure 18. Situation of brown forest soils in Hungary ............................................... 26
4.3. Figure 19. Brown forest soil .................................................................................. 27
4.4. 20. Figure Cultivation of brown forest soil ................................................................. 28
4.5. Figure 21. Situation of Chernozem soils in Hungary .................................................. 30
4.6. Figure 22. Main characteristics of calcareouschernozem soil ........................................ 31
4.7. Figure 23. Water erosion on chernozem soil ........................................................... 31
4.8. Figure 24. Situation of meadow soils in Hungary ...................................................... 32
4.9. Figure 25. Main characteristics of meadow soil ......................................................... 33
4.10. Figure 26. Situation of alkaline soils in Hungary .................................................... 35
4.11. Figure 27. Main characteristics of alkaline soil .......................................................... 36
4.12. Figure 28. Situation of sandy (skeletal) soils in Hungary .......................................... 38
4.13. Figure 29. Soil characteristics of sandy soils ............................................................. 38
5.1. Figure 30. Conventional tilled soil surface ............................................................... 41
5.2. Figure 31. No-tillage ............................................................................................. 43
5.3. Figure 32. Strip tilled soil surface ............................................................................ 45
5.4. Figure 33. Ridge tillage ......................................................................................... 47
5.5. Figure 34. Tillage systems in Western Europe .............................................................. 48
5.6. Table 2. Comparison of different tillage systems ....................................................... 48
6.1. Figure 35. Soil compaction caused by anthropogenic factors on the surface (wheel-track) and by cultivation tools ................................................................................................................. 50
6.2. Figure 36. Soil compaction caused by tillage equipment ........................................... 51
6.3. Figure 37. The impact of soil moisture condition on the depth expansion of compaction powers 52
6.4. Figure 38. The impact of compaction on the moisture and air cycle of soil .................. 54
6.5. Figure 39. Soil compaction blocks root growth ......................................................... 54
6.6. Figure 40. The maximum depth of tillage and deep loosening on calcareous chernozem soil 56
8.1. Figure 41. Conventional tillage with mouldboard plough ........................................... 67
8.2. Figure 42. Conventional tillage with reversible plough .............................................. 67
8.3. Figure 43. Tillage with heavy cultivator ..................................................................... 68
8.4. Figure 44. Ripper tillage equipment ........................................................................ 69
8.5. Figure 45. Disc harrow ......................................................................................... 70
8.6. Figure 46. Seeding cultivator .................................................................................. 71
8.7. Figure 47. Strip-tillage .......................................................................................... 72
8.8. Figure 48. Combined soil tillage and sowing ............................................................ 73
A táblázatok listája

10.1. Table 3. Classification of the produced crops based on their soil protection effect. ................. 89
10.2. Table 4. Guidelines of plot development on slopes: plot size per slope category ...................... 91
10.3. Table 5. Guidelines of plot development on slopes: plot width per slope category .................. 92
Soil Cultivation and Land

Janos Nagy – Tamas Raton
1. fejezet - 1. Environmental factors determining soil fertility and field crop yield

The climate of certain regions in Hungary is significantly different from each other as a result of the different factors determining the climate. The main climate determining factors are solar radiation, elevation above sea level, terrain configurations, the material of the soil surface, vegetation and circulation. Hungary is located in the temperate, continental climate zone, between 45° 48’ southern and 48° 35’ northern latitude, in the 70-1000 m zone above sea level. The country is on the border of the wet oceanic, dry continental and Mediterranean regions with dry summers and wet winters. The water surface and various soil types in Hungary affect the climate only slightly and locally. The Mediterranean Sea (subtropical effect) and the Atlantic Ocean (oceanic effect) have much larger impact. 68% of Hungary’s area is flatland (70-150 m above the sea level), 29% is hill country between 150-400 m above sea level and the proportion of areas above 400 m is 3%. The climate of flatlands is relatively more uniform, while that of hill countries are much more versatile.

In the future, climatic factors are going to change globally mainly as a result of human activities. This impact can also affect Hungary’s climate. Based on the data of a long series of indirect and direct measurements, it can be considered a fact that the concentration of gases which affect the greenhouse effect of Earth’s atmosphere increases. Based on the assumed increase of global temperature, MIKA (1991) determined the expected temperature and precipitation conditions of Hungary by 2120, using empirical methods. Based on the calculations and depending on the extent of global warming, Hungary would face a warmer and more drought-stricken climate in the first half of the period and the other half would be warm and wet. As a result of the reduction of the ozone content in the stratosphere, radiation will become more intensive in the UV-B range, which is the active spectrum from the biological aspect.

1. 1.1 Light

Of environmental factors, light is of primary importance and cannot be replaced by anything. Radiation energy from the Sun reaching the surface is of substantial importance from the aspect of climate. The electromagnetic radiation from the Sun reaches the soil surface, providing enormous amounts of energy constantly. The intensity of solar radiation fluctuates between 1350-1400 W/m² outside the Earth's atmosphere with yearly periodicity (extra-terrestrial radiation, ETR). Of the radiated solar energy, the whole Earth-atmosphere system reflects 30% towards the space and the remaining 70% is transformed in various energetic processes. 28-29% of the incoming radiation is absorbed by the atmosphere, 41-46% reaches the soil surface (global radiation, GRAD). The amount of energy reaching the soil surface depends on the angle at which the radiation reaches the surface, as well as the distance it has to take through the atmosphere, the elevation above sea level in the examined area, the amount of water vapour in the atmosphere, mist, clouds, multi-atomic gases and atmospheric contamination. In very clear weather, the extent of surface global radiation could reach even 70% of the radiation reaching the upper limit, while it could decrease to below 20% if there is a thick cloud cover. In Hungary, the global radiation reaching the surface in the summer period is 3200-3600 MJ/m², while its average value over the year is between 4300-4800 MJ/m² based on the data obtained between 1951-1980. Part of the global radiation reaching the surface is absorbed by the surface and the rest is reflected back into the atmosphere, depending on the albedo. The albedo of the surface depends on its color, moisture conditions, roughness and the material covering the surface (vegetation cover, crop residues, snow etc.). In the case of dry soil, the albedo is between 0.14 (clay) and 0.37 (sand drift). The daily values of the solar invariant, extra-terrestrial radiation and global radiation in Debrecen, as well as their changes over the year are shown in Figure 1.

Certain part of the rays emitted by the Sun is visible and the rest are invisible (infrared and ultraviolet rays with chemical impact). Around half of the whole radiation spectrum falls within the visible range. The ecological significance of light depends on the proportion of visible and invisible rays, as well as whether they reach the surface directly or indirectly. 99% of the spectrum of the global radiation reaching the surface is between 300-4000 nm, while the spectral range of the photo synthetically active radiation is between 400-700 nm. 42-47% of the total global radiation reaches the surface in the photo synthetically active range (PhAR). However, this ratio is higher in cloudy weather than in clear weather. Plants use higher amount of diffused light whose composition is also more favourable than that of direct light, as it contains more yellowish red rays that are more favourable for plants. The more clouds, water vapour and dust are in the atmosphere, the more diffused light there is. The
1. Environmental factors determining soil fertility and field crop yield

clearer and more invisible the air is, the higher the extent of direct radiation is. Measurements performed in Budapest show that around half of the yearly global radiation in Hungary reaches the surface as diffused radiation.

The yearly sum of sunshine duration in Hungary is 40-47% of the astronomic sunshine duration. The proportion is the worst in December when this value is only 15-20%, while it reaches 55-65% in the middle of the summer. The maximum sunshine duration in a year is more than 2150 hours, while the minimum duration is less than 1900 hours. The sunniest part is the south eastern region of the Danube-Tisza mid-region with its more than 2000 hours of sunshine in a year. The western edge of the border has less than 1800 hours per year. The monthly sunshine duration values are around 140-300 hours in the growing season (April – October).

The produced crops need light as an energy source for the assimilation of carbon dioxide and the production of organic matter. Light has an impact on crop growth, development, shape, its anatomical structure, transpiration, nutrient uptake and geographical dispersion. The effect mechanism of the radiation absorbed by the vegetation can be classified into three groups: thermic, biochemical and photo morphogenetic effect. More than 70% of the absorbed radiation is transformed into heat energy in the crop stand (thermic effect). The highest proportion of this heat energy is used in evaporation and transpiration, while the remaining considerable amount of energy is used in heating the surrounding air. Plants are able to regulate their own temperature with evaporation. Only a very small proportion (1-5%) of the radiation energy in the growing season is used in photosynthesis (biochemical effect). Radiation plays an important role in the growth and development of plants (photomorphogenetic effect). The photomorphogenic effect is determined by the energy of the incoming radiation, the periodical temporal change of radiation, as well as the dark and light periods and their lengths. Flowering calls for such quality change which depends on two external factors: temperature and the length of days. Certain crops have special environmental needs during the transition to the generative phase: the duration of daylight. Some plants flower after long day, others flower after short day illumination. The reaction of plants to the relative length of day and night is called photoperiodism. Plants that need longer daytime illumination for the induction of flower buds are called long day plants, while those which need shorter illumination are called short day plants. Certain plants’ development is independent of the length of the day, these are called day-neutral plants.

1.1. ábra - Figure 1. Values of the solar invariant, extra-terrestrial radiation (ETR) and global radiation (GRAD) in Debrecen

(Huzsvai et al., 2004.)

2. 1.2. Air temperature
1. Environmental factors
determining soil fertility and field crop yield

Temperature is among the fundamental elements of weather and climate, as it determines the range of crops which can be produced and strongly influences yield.

Air temperature is indirectly influenced by solar radiation. The surface absorbs solar radiation in accordance with its albedo and the absorbed energy is the main source of air warming. Air warming starts from the soil surface.

The yearly mean temperature is 9-11°C in the flat areas of Hungary. The southern – south eastern part of the country is around 3°C warmer than the northern part which is in connection with the difference of the latitude. The terrain configurations greatly affect temperature, the temperature decrease accompanying the increase of elevation results in the relatively short and small mountains of medium height emerging from the warm flatlands and hill countries like a cold island. Hungarian mountains can be characterised by their cold temperature, usually between 6-7 °C. In the Great Plain and the flat areas of the Transdanubian region with the exception of the Western Transdanubian part, the yearly mean temperature is between 10-11 °C. The yearly mean temperature is between 9-10°C in the northern periphery region of the Great Plain, in the Nyírség region, in the Western Transdanubian region and in the hill country bordering the Transdanubian Mid-Mountains.

The mean temperature of January, the coldest month in Hungary, falls between -4 °C – 0°C. In July, the hottest month, temperature decreases from the south to the north and increases from the west to the east. In the summer period, the north western-northern parts of the country are the coldest, (mean temperature: 19°C), while the hottest part is the south eastern area of Hungary (22°C).

From the aspect of temperature, days can be classified as severely cold, winter, frosty, summer, torrid and hot. On severely cold days, the temperature minimum is minus 10 °C or lower. On winter days, the temperature is not higher than 0 °C. On frosty days, the temperature minimum is 0 °C or lower. On a summer day, the maximum temperature is 25 °C or higher. On a torrid day, the maximum temperature is 30 °C or higher, while on a hot day, the maximum temperature is 35 °C or higher.

The growth and development of plants calls for a determined amount of heat and heat impact duration. For this reason, both the absolute heat sum and its temporal distribution are important. In the temperate zone, the light and heat circumstances are of periodical nature, showing seasonal and daily fluctuation. Plants have different heat demand, depending on their development stage. Usually, germination needs lower temperature than growth, while flowering calls for warmer temperature than growth. Accordingly, the geographical dispersion of plants is in close correlation with the geographical distribution of heat circumstances.

Temperature has a direct effect of the vital activities of plants and each physiological process. The effect of temperature on photosynthesis is complex and it depends on the intensity of light and the carbon dioxide content of the atmosphere. For several agricultural crops, the temperature optimum of photosynthesis is relatively low. This is one of the reasons why high starch content crops (cereals, sugar beet, potato) provide higher yields under cold climate than in warmer regions. Respiration becomes more increased with the elevation of temperature. However, the increased respiration is not permanent at very high temperature, it quickly decreases in a few hours. Usually, transpiration is low at low temperature and it becomes more increased with increasing temperature. If water loss outweighs the water uptake of plants, withering will occur soon. Depending on the soil temperature, the water uptake of roots increases between 0°C - 60-70°C in the temperate zone in the case of several plants. The impact of temperature on water uptake can be partly explained by the fact that the water viscosity, the permeability of the cell walls and the physiological activity of the root cells change. The uptake of mineral nutrients shows down at low temperature as a result of reduced respiration and the reduction of the cell wall permeability.

By the impact on the microbiological activity of the soil, temperature indirectly affects plant growth. As a result of the increasing or decreasing activity of the microorganisms, the temperature and composition of soil are change.

Temperature has an impact on the jarovization processes of long day plants, the quality changes in the apical cells of the stem which are needed at low temperature in order for the plant to enter the generative stage from the vegetative stage.

Temperature during the growing season greatly affects the yield of plants and also determines whether they can be produced. Growing season basically refers to the frost-free period between the last harmful spring frost and the first harmful autumn frost.
Temperature below the freezing point is harmful and its impact can be observed in multiple ways. During freezing, the plant’s temperature decreases below the freezing point; ice formation begins and the water from the plasm freezes in the intercellular spaces. Frost damage means that the plant is unable to take up water from the frozen soil. Winter burn happens if the field is covered with ice for a longer period, thereby hindering respiration and the crop will perish as a result of oxygen loss. Freezing rain could also cause significant damage, as the crop parts are physically damaged under the weight of ice, the branches of woody plants break off and they suffocate due to the thick ice. The damage done by frost heaving is based on the commonly known phenomenon when water freezes to ice and its volume increases by a tenth. In the late winter and early spring, it often occurs that only the soil surface melts during the quick snow melting and the lower layers remain frozen. The snowmelt completely fills up the surface gaps; therefore, the air which is produced as a result of the frost at night elevates the soil surface with the plants in it sometimes even by 3-5 cm and rips the roots.

Too high temperature is also harmful and enough to do direct damage to the protoplasm of plant cells. The temperature limits of plant life are very different. The minimum determines the borders of geographical dispersion. This value changes in each species and variety and also in each development phase. Plant development is the fastest at the optimum value. The maximum is the upper limit at which vital processes can still work. Only the heat-resistant inert organs (seeds, spores, buds) can tolerate the extreme values of the lower and higher limits.

The vegetation of the temperate and cold zones is more cold-resistant than heat-resistant, since very high temperature is rather infrequent in temperate and cold zones; therefore, heat resistance does not develop in the vegetation. Also, they tolerate frequent strong heat fluctuations much less than short-term low or very high temperature.

### 3. 1.3 Wind

The horizontal movement of air is called wind, whose direction, speed and impacts can be rather different. Even in the case of calmness, the air is in constant motion. Wind is an important ecological factor and it greatly regulates climate. Usually, wind is determined based on its direction and speed. Wind speed refers to the point of the compass from which the wind "blows". Wind speed refers to the distance the air particles travel during a time unit. Its measurement unit is km/h or m/s. The most frequent wind direction is called the prevailing wind direction. North eastern winds prevail in the western and central areas of Hungary. As a result of the diverting and protection effect of the Alps, the prevailing wind direction is northern close to the western Transdanubian border of the country. The prevailing wind direction is north eastern or northern in the north eastern part of the country, in the area bordered by the Tisza and the various Körös rivers, and also in certain areas of the Southern Transdanubian region.

In Hungary, there are no great differences in wind speed during a given year. The windiest period is early spring, when the average wind speed value is between 8-11 km/h. From this period, wind speed gradually decreases during the year and the minimum value in late summer – early autumn is 5-13 km/h.

The effect of wind can be direct and indirect. Its direct effect is shown in the transportation of yield, seeds, spores and pollen, as well as the mechanical damages on plants. As a result of its indirect effect, the temperature and moisture content of soil changes, the transpiration of plants increases and their photosynthesis decreases. The harmful effect of the wind is shown differently in each season. Winter windstorms remove the snow cover from the sowings; therefore, strong frosts can damage them. In other places, it can accumulate the snow cover in a thick layer and the sowings can perish underneath, while several diseases can damage the vegetation. The spring melting of the snow cover of uneven thickness may be followed by water cycle inequalities in the field which hinder spring activities and the development of an even crop stand. Windstorms in the spring increase the evaporation of the moisture stored in the soil during the winter, they inhibit the sprouting of sowing seeds and the development of young crops. Dry storm-winds in the summer could cause significant damage to our culture crops, they terminate the favourable crop stand climate, increase the crop transpiration and cause lodging in the case of cereals. Wind causes soil deflation which could have a large extent on each soil, but especially on sandy and marsh soils in the spring, when not only sand-blasts cause damage, but the wind-storm also carries away the sprouted young plants.

### 4. 1.4. Precipitation

From the aspect of agriculture, precipitation is the main element of the Hungarian climate which is prone to drought. Since the water supply of field crops is mainly provided by atmospheric precipitation, one of the main
climatic elements of agricultural production. The precipitation in Hungary usually does not meet crops’ needs, the precipitation supply covers crops’ water need to a moderate extent, as precipitation is a rather variable element both spatially and temporally.

There are various forms of precipitation: rain, hail, freezing rain, snow and microprecipitation which are formed close to the surface (dew, rime, hoar). Of these, dew is of special importance from the aspect of crop production. Dew is formed at temperature above the freezing point when the soil surface and the living and lifeless objects on the surface cool down as a result of emanation to an extent that water vapour is extracted from the air of higher temperature and it forms a thin water cover on their surface. The transpiration of plants covered in dew decreases which could lead to the reduction of the yield decreasing effect of a drought summer period. Furthermore, dew can also form in the soil which is then called soil dew. In Hungary, the total amount of water originating from dew in a year is 63 mm, according to calculations.

Precipitation endowments can be characterised by its yearly, monthly and daily amounts, the length of precipitation-free periods, as well as the intensity of precipitation. The yearly amount of precipitation is between 500-800 mm in Hungary (Figure 2). The variability of precipitation is shown by the fact that the yearly amount is only 290-320 mm in certain areas of the Great Plain in the driest years, while its value is between 1100-1400 mm in the south western areas of the Transdanubian region and in the highest areas of the mid-mountains, while it is often between 850-900 mm in the dryer regions of the Great Plain in the wettest years. Therefore, in the wettest years, the amount of precipitation might easily be three times as that in the driest years. The variable nature of precipitation is shown by the fact there could be differences even between the yearly courses formed on the basis of the averages referring to the different durations. The temperate zone areas with continental climate are characterised by the summer precipitation maximum and the winter precipitation minimum, while areas with Mediterranean climate are the other way round. The yearly course of precipitation in Hungary is regulated by the continental, Atlantic and Mediterranean effect, whose proportion can be rather variable each year.

In addition to knowing the amount of precipitation, the temporal distribution of incoming precipitation is a rather important issue. The number of days with measurable precipitation (>0.1 mm) is 120-140. The number of days with significantly more effective precipitation (1 mm or more) is 80-105. The number of days with 5, 10 and 20 mm or higher is between 35-45, 15-31 and 4-12, respectively. Days with precipitation above 5 mm can be considered standard, as this amount of rainfall can increase the moisture stock of the soil despite the evaporation losses and the interception of precipitation by plant leaves. A significant part of precipitation whose intensity exceeds the water intake capacity of the soil flows off the surface or evaporates. The distribution of rainfall represents Hungary’s climate that is prone to drought, as the most frequent precipitation sums are close the average (50%), while minimum amounts are less frequent and monthly amounts close to the maximum are the least frequent.

The amount of precipitation in the growing season (April-September) is important from the aspect of crop production. Winter precipitation has special importance from the aspect of the water supply of the produced crops. The available water stock left in the soil from the winter precipitation covers plants’ water demand only partially. Calculating with 2 mm/day average evapotranspiration, 100 mm available moisture content is enough for 50 days. For this reason, the precipitation in the summer period is of great significance from the aspect of plants’ water supply. Under Hungarian circumstances, the summer precipitation sum is 55-65% of the yearly amount.

Periods without precipitation could result in significant yield decrease. The probability of periods without rainfall changes throughout the year. According to various examinations, longer periods without any rainfall are likely to occur most frequently in early spring and early autumn, while the rainfall peaks in early summer are very unlikely to happen, similarly to the winter period.

A significant part of the winter precipitation reaches the surface in the form of snow. Snow plays an especially important role form the agricultural aspect, mainly in terms of the frost damage of autumn-sown crops. The first day of snow cover is between 1st-15th December in the northern and western part of the country, while it can be expected after 15th December in the southern periphery of the Great Plain. The last days of snow cover are to be expected between 15th – 28th February in the Great Plain and the eastern parts of the Transdanubian region, while it could last until 1st March in the northern part of the Great Plain and in several areas of the Transdanubian region. The number of days with snow cover is mostly affected by the elevation above the sea level. Its value is 30-35 days in the southern areas of the Great Plain, above 40 days in the Southern Transdanubian region, and the western half of the Little Plain, while it could exceed 100 days in the mountains. The average thickness of snow cover is 4-6 cm in the Great Plain, more than 8 cm in the northern parts of the
1. Environmental factors
determining soil fertility and field
crop yield

Danube-Tisza mid-region and 4-7 cm in the Transdanubian region. As a result of repeated melting and freezing, an ice cover is formed on the surface of the snow cover, resulting in deteriorated oxygen supply of autumn-sown crops which stand the winter and various illnesses could damage the population (e.g. snow-mould).

1.2. ábra - Figure 2. Average yearly precipitation (Debrecen, 1989-2008)

Source: www.met.hu

5. 1.5 Hydrological factors

The hydrological characteristics of the production site greatly determine the water, heat and nutrient cycle and the erosion features of the production site soil, as well as its drought and drainage water sensitivity. The hydrological aspects depend on the geological location, exposure and the terrain of the production site, as well as the characteristics of the reservoir and the hydrogeological features of the region.

The hydrology cycle of the soil means the collective of complex consecutive processes which results in the amount of water stored in the soil changing constantly. The soil water balance shows this change as a function of the hydrological factors.

The water balance of the soil is based on the law of mass conservation which says that the moisture content of a given soil column which has limited volume cannot increase without water replenishment of external origin (e.g. infiltration or capillary elevation) and it cannot decrease without moisture being passed into the atmosphere (by evaporation or transpiration) or into deeper soil layers.

The water balance of the soil can be calculated for a given soil volume; therefore, water balance can be interpreted for both a small-sized soil sample and a whole catchment area. From the ecologic and crop production aspects, the best is to calculate the water balance for the root zone of unit basic area (Figure 3). The water balance of the root zone is determined for a given period of time and the following equation is used in general:

\[ \Delta \Theta = (Cs + K + Fbe + Tbe + Obe) - (P + I + TR + Fel + Tel + Oel) \]

Where: \( \Delta \Theta \) - change of the moisture content stored in the root zone (mm)

Cs - amount of precipitation (mm)
1. Environmental factors determining soil fertility and field crop yield

K - amount of water condensed from air (mm)

Fbe - surface afflux (including irrigation) (mm)

The capillary water flow from the soil layers beneath the root zone (mm)

Obe - lateral afflux (mm)

P - direct evaporation from the soil surface (mm)

TR - transpiration (mm)

I - interception (mm)

Fel - surface runoff (mm)

Tel - deep infiltration from the root zone (mm)

Oel - lateral runoff (mm)

Considering the fact that the extent of lateral water movement is neglectable in the unsaturated zone in comparison with the vertical infiltration and that the amount of water condensed from the air and retained by the plant surface is usually very low, the values of Obe, Oel, K and I are usually neglectable.

The amount of atmospheric precipitation depends on the geographical location of the region and the microclimate of the production site. The surface afflux and runoff is significantly determined by the characteristics of the terrain, the unevenness of the microterrain and the water conduction ability of the soil. This latter has to be considered in the proportion of rainfall intensity in all cases, as the amount of water reaching the surface can only infiltrate into the soil as long as the rainfall intensity is lower than the saturation water conduction ability of the soil.

The deep infiltration from the root zone and the capillary water elevation are affected by the structure and the mechanical composition of the soil, as well as the depth of groundwater.

1.3. ábra - Figure 3. Elements of soil water balance

B = CS + K + Fbe – Fel – I - infiltration

(Várallyay, 2004)
I. Environmental factors
determining soil fertility and field
crop yield

It can be seen that the hydrological factors and the proportions between each factor fundamentally determine the water balance characteristics of the soil. The hydrological factors are influenced by both zonal and azonal factors (e.g. hydrogeological circumstances, terrain, distance from seas and oceans etc.).
2. Methods of influencing the water, heat and air management of soils

1. 2.1 Water management of the soil

The water management of the soil can be characterised by the amount of water potentially stored in the soil, the mobility of water and its spatial and temporal change. From the aspect of land use, we focus on the quantity issues of soil moisture, as well as its availability to crops and the factors influencing this availability.

One part of soil moisture is adhered to the soil grains, while the other part is in the pore space of soil. Above the freezing point, the soil moisture in the fully saturated bi-phase soil layers filled to the maximum field capacity (VKmax) has liquid state, while in tri-phase soil layers where moisture fills only a certain part of the pores, water is present in liquid and steam state in the soil.

The actual moisture content of the soil can be expressed in weight %, volume %, mm and m3/ha. Moisture content expressed in weight % shows how many grams of moisture are stored in 100 g soil. The moisture content of the volume % of the soil provides more information, expressing the moisture content (cm3) in 100 cm3 soil. In order to calculate this value, one has to know the soil’s mass per volume which has to be multiplied by the moisture content expressed in volume %. From the practical aspect, expressing the water stock in mm might also be needed. In order to determine this value, one has to know the moisture content of the soil expressed in volume %. Since 1 volume % moisture content equals 1 mm precipitation in the 10 cm soil layer, the volumetric moisture content has to be multiplied with one tenth of the thickness of the given soil layer expressed in cm.

The moisture profile of the soil can be obtained by graphically depicting the moisture values of the 1-5-10 cm layers of the soil profile against depth. A wetting profile means that the amount of precipitation is higher than evaporation (Figure 4). A desiccation profile means that the amount of evaporation is significantly higher than the amount of precipitation.

2.1. ábra - Figure 4. Wetting soil moisture profiles
There are typical differences in each layer concerning the yearly course of the temporal changes of the soil moisture content. Generally, the yearly fluctuation of the soil moisture is the highest in the upper layers of the soil and the extent of fluctuation decreases with the increase of depth. The soil reaches the peak of its moisture stock at the end of winter, while it usually reaches its minimum in August. The change of the yearly amplitude of moisture content depends on the precipitation and evaporation circumstances that are also greatly determined by the groundwater depth. Depending on the amount of precipitation and the soil type, there could be significant differences in the depth of the leak. In the case of clay soils, the increase in moisture content caused by precipitation can be hardly determined under 1 m, while in the area of the Hajdúság loess ridge, the penetration depth of moisture fluctuation could even reach 2-3 m. SZÁSZ (1997) demonstrated a linear correlation between the moisture amplitudes of each soil layer and the logarithm of depth until 100 cm depth in adobe soil close to Debrecen. The daily fluctuation of the soil moisture content could be tracked until 40-50 cm depth and it was the strongest at the 0-20 cm depth.

Calculating the absolute value of moisture content is not enough to determine the moisture stock available to the crop, since a given moisture content value represents different amounts of available water in each soil depending on the force binding that moisture. The moisture in the pore space of the soil can be held back by pores which fall into the capillary size range, as the water stored by them is affected by the adhesion powers between the water molecules and the water, the cohesion formed on the water/air edge surface and the gravitational powers. In pores which fall into the gravitational size range of larger diameter, water seeps downward as a result of gravity. The water conduction ability and air management of the soil are determined by the number of pores. The soil moisture retention (pF) curve of the soil describes the extent of binding forces against the volumetric moisture content of the soil. The extent of these binding forces is determined on the basis of the base 10 logarithm of the suction power expressed in water column cm (pF value). The pF curve of the soil provides the following information: wilting point (WP; pF=4.2), field water capacity (FC; pF=2.5) and maximum water capacity (MC; pF=0). The following factors can be calculated: the amount of water available to the crop (AW=FC-WP), total porosity of the soil and distribution of pores by size. Based on Figure 5, the typical points of the pF curves of a sandy, adobe and clay soils can be compared to each other. It can be seen that the field water capacity is the largest in the case of the clay soil, followed by adobe soil and the lowest value was obtained in sandy soils. The wilting point values had the same ranking, while the amount of water available to
the crop was the highest in the case of adobe soils. The amount of water available to crops was 80 mm in sandy soils in the upper 100 cm, 160 mm in adobe soils and around 130 mm in clay soils.

During cultivation, we change the number of soil pores, the distribution of pores by size; therefore, we fundamentally influence the water management of the soil. During the selection of cultivation procedures, attention must be drawn to the role of the chosen cultivation system in water management in addition to establishing the soil conditions needed by the given crop. Cultivation has its impact on the soil in the macropore range; therefore, increasing the loose character of the soil increases the volume of the pores in the gravitational size range which serve water transfer and compaction has an inverse effect. The volume of pores falling into the capillary size range does not change or only slightly changes as a result of cultivation; therefore, the amount of water stock potentially available to crops is not affected.

During cultivation, the main objective is to preserve water from spring to autumn and the infiltration of the incoming precipitation into the deeper layers of the soil is of chief importance in the autumn period. Under Hungarian production circumstances, water preservation is one of the most important tasks of cultivation. Our measurement results in Hungary showed that the soil protection-focused, zero tillage cultivation was more favourable from the moisture preservation aspect in comparison with the traditional cultivation method based on ploughing. The soil conditions established with the autumn primary tillage contributes to the infiltration and storage of the autumn and winter precipitation in the soil. The moisture content stored in the deeper layers of the soil could serve as a reserve for the summer water need of crops; therefore, the damage caused by drought could be reduced.

The stubble-stripping performed in the summer period has a significant role from the aspect of preserving soil moisture. Water vapour is transported in the soil either by the streaming air or by diffusion from places with higher temperature and higher relative humidity to pores which have lower partial pressure. Therefore, the mobility of water vapour in the soil is elicited by difference in temperature. The shallow loosened soil layer established during stubble-stripping quickly cools down during the night, water vapour moves from the deeper layers towards the surface and the moisture precipitates out on the lower part of the ploughed up layer, soil dew is formed (Figure 6). The water vapour which diffuses from the deeper layers of the soil towards the surface could reach 30-35 mm and it moistens the surface soil, resulting in improved cultivability and biological activity.

2.2. ábra - Figure 5. pF curves of sandy, adobe and clay soils

![Figure 5. pF curves of sandy, adobe and clay soils](http://www.aardappelpagina.nl/explorer/pagina/soilwater.htm)
2. Methods of influencing the water, heat and air management of soils

2.3. ábra - Figure 6. The effect of cultivation on the moisture content of the soil under various weather circumstances in adobe soil

(Szász, 1997.)

2. 2.2 Air management of the soil

Soil air has an important role in the oxygen supply of crops, as it influences the intensity of soil biological and chemical processes. The pores of the wet soil is filled partially by water and partially by air \((P_{\text{total}} = P_{\text{water}} + P_{\text{air}})\). Depending on the moisture conditions of the soil, the air content of the soil pore space could range between close to zero to nearly 100% (soil dried at 105 °C). Water occupies the place of the air which is squeezed out as the soil is becoming moister and the reverse process takes place as the soil is drying. The air management of the soil is determined by its grain composition, structure, as well as the size distribution and moisture content of its pores.

The so-called minimum air capacity is one of the main factors of the air management of the soil and it represents the air content of the soil wetted to its field capacity (FC). The minimum air capacity of the sandy soil is 30-40% in the percentage of the pore space, while it is 10-25% in adobe soils and below 10% in clay soils. In the case of this moisture condition, the soil pores in the capillary size range \((0.2-10 \text{ cm})\) are filled with water and the gravitational pores are filled with air. Therefore, the water/air ratio determined in the case of the field water capacity shows the proportion of the capillary/gravitational pores to each other. If the moisture content of the soil is lower than the field water capacity, certain part of the pores of the capillary size range will also be filled by air. The air content of the upper soil is higher than the minimum air capacity on a significant proportion of cultivated soils during most of the year, since the moisture content of the soil can be close to the value of field water capacity only during the early spring period.

Different plants have different needs for good air conditions in the soil. Expressed in the percentage of the pore space of the soil, grass species have 12-20% air need, while that of cereals is 20-30% and this value is 30-40% in the case of sugar beets. The minimum air capacity of the soil is the critical condition for plants.

If we compare the extent of the minimum air capacity and the need of plants, it can be seen that these two values are different especially in the case of plants that need good air supply in the soil (potato, sugar beets, maize, alfalfa, hemp). The value of minimum water capacity could be much lower than crops’ needs in the case
of heavy soils and deteriorated, strongly compacted soil conditions, since there are very few gravitational pores in the soil. Under such circumstances, air shortage might occur in the soil as a result of a large amount of precipitation or irrigation. The airless character of the soil will end once a certain part of the gravitational and capillary pores will be filled by air as a result of the deep infiltration or evaporation of moisture and the soil will reach the water/air ratio that is adequate for plants. By using the loosening processes that terminate the compacted character of the soil, the proportion of gravitational pores serving the purpose of air supply and water conduction can be significantly increased within the given soil volume, thereby increasing the minimum air capacity of the soil. If there is a large amount of precipitation after loosening the soil, the air shortage period will be shorter, since the reduction of the moisture content of the soil layers filled up to nearly their MC value will result in a water/air ratio favourable for crops even at the FC moisture content.

In order to evaluate the air management of the soil, one has to know its air permeability. Usually, the composition of soil air is not the same as that of atmospheric air. The air permeability, biological activity and – depending on the root activity – the CO2 and O2 content of soil air could significantly differ from atmospheric air. If the CO2 content of soil air is higher than 5% and its O2 content is lower than 10%, the metabolic processes of the produced crops will be disturbed.

The continuous air exchange between air of the soil and the atmosphere has to be provided in order to cover the oxygen need of crop and soil life. During the evaluation of the air management of the soil, it is important to know the air permeability of the soil, which represents the amount of air streaming through a cross-section unit of one unit thickness as a result of one unit pressure difference in a time unit. Its value can be determined with manometric and rheometric methods. Air exchange between atmospheric and soil pores can be facilitated by increasing soil porosity. The shallow cultivation which provides the properly loosened soil surface can significantly improve air exchange and it is recommended to be performed in the case of crusty soil surfaces.

### 3. 2.3 Heat management of the soil

Of climatic factors, soil temperature has an important role. The soil absorbs and stores certain part of the incoming solar energy, before transferring it back to the atmosphere. No maps have been prepared about the temperature distribution of Hungary’s soils, because the soil temperature is too microclimatic for this purpose. Therefore, the specific value of soil temperature is determined by many factors at the same time.

The germination, growth and development of crops of higher rank, as well as the vital activities of the microorganisms living in the soil, thereby the nutrient cycle of the soil depend on soil temperature. Soil temperature affects the decay of the mineral parts of the soil, as well as the mobility of water in the soil (in liquid and vapour forms).

The heat sources of the soil are radiation coming from the Sun and the internal heat of the Earth. The temperature of the precipitation and heat produced as a result of the physical-chemical and biological processes in the soil (precipitation of moisture, freezing, decomposition of organic substances) affect soil temperature, but the source of heat energy is still the radiation from the Sun in this case.

The effect of heat reaching the soil depends on the heat capacity, heat conduction ability and temperature conduction ability of the soil.

The extent of heating up the soil is determined by the heat capacity of the soil. The heat capacity of the soil is the amount of heat that increases the temperature of 1 cm3 soil of original structure by 1 oC. The extent of heat capacity can be obtained by multiplying specific heat and density. During the determination of the soil heat capacity, mass per volume is used instead of density. The specific heat of soil components, as well as the looseness of the soil fundamentally influences the value of heat capacity. Since the specific heat of water is several-fold higher than that of the solid soil components, heating up wet soil to the same specific heat level calls for 3-4 times as much heat as in the case of dry soil. The heat capacity difference of the soil is basically caused by the difference of the proportion of water and air in the soil.

Figure 7 shows the change of the heat capacity of soil against moisture content and the looseness of soil. There is a linear correlation between the heat capacity of the soil and the amount of water in the soil. The heat capacity of the soil increases with its moisture content and volumetric weight. If we terminate the compacted soil condition (stubble) with cultivation interventions which increase the loosened character and reduce the volumetric weight of the soil (ploughing), the heat capacity of the cultivated soil layer decreases. Therefore, as a result of the same heat quantity, the loosened soil layer becomes hotter and also cools down quicker with the reduction of solar radiation.
2. Methods of influencing the water, heat and air management of soils

2.4. ábra - Figure 7. Heat capacity of chernozem soils against moisture content and soil looseness

As the energy from solar radiation reaches the soil surface, it is spread from particle to particle. The heat conduction ability of the soil represents the heat amount that is passed through 1 cm² cross-section of the soil in a second if the temperature change is 1 °C/cm if measured perpendicularly to the cross-section. There is a correlation of second degree between the value of heat conduction ability and the moisture content of the soil. The wetter the soil is, the higher its heat conduction ability is, since the heat conduction ability of water is around 100 times higher than that of air. Heat fluctuation is lower in the upper layers of soils with good heat conduction ability, while it is higher in deeper layers in comparison with a soil with poor heat conduction ability. For this reason, wet soils with good heat conduction ability heat up slower as a result of their higher heat conduction ability, but they conduct heat better. This is the reason why dry sand is strongly heated up in summer sunshine, as the accumulated heat amount due to its low heat capacity cannot transfer the heat to the lower layers.

The heat conduction ability of the soil is an important concept from the physical point of view, but it does not determine the heat management characteristics of soils in itself. It is much more important to know how much temperature change is caused by the heat energy conducted by means of the heat conduction ability of the soil in the given layer of the soil.

The temperature transfer capacity expresses the heating effect of the heat streaming in the soil and its value can be obtained by the ratio of the heat transfer capacity and heat capacity.

Figure 8 shows the temperature transfer capacity of the soil against its moisture content and looseness. It can be seen that the temperature transfer capacity is low both in the case of dry and rather wet soil conditions. In dry soils, heat energy is transferred into deeper soil layers less, since the air filling the pores has low heat transfer capacity. Under such circumstances, the surface soil layers heat up and cool down more easily as a result of the transferred heat energy. The heat transfer capacity of soils containing high amounts of water is high and their heat capacity is even higher; therefore, their temperature transfer capacity is low. As a result, the soil remains cold even in the case of abundant heat energy uptake.

2.5. ábra - Figure 8. Temperature conduction ability of chernozem soils against moisture content and soil looseness
Based on the correlation of moisture content, soil looseness and the temperature conduction ability of the soil, it is possible to evaluate the heat management of the main soil types classified on the basis of their physical characters.

Sandy soils can hold back only little water from the gravitational pull. If moist, sandy soils have low heat capacity and heat transfer capacity. Sandy soils are also called burning hot soils, because the surface layers of the soil warm up easily in the summer, as opposed to clay soils which are often referred to as cold soils. As a result of the weak heat transfer capacity of the soil, the heat energy from the surface soil is transferred to the deeper layers less if the heat reserves of the soil is also much lower. Due to all these characteristics, the yearly and daily fluctuation of the sandy soil’s temperature is much higher than that of the adobe and clay soils.

The heat management of adobe soils is rather favourable. With the exception of extreme weather cases, these soils usually have enough moisture, so that the ratio of the mentioned heat characteristics is adequate. For this reason, the surface layer of adobe soils does not warm up too much, while even the extent of cooling down is not unfavourable either.

Clay soils are also called cold soils, as they hold significant amount of water and their heat capacity and heat transfer capacity are rather high. Usually, their temperature is lower, they warm up slower in the spring and they do not reach the optimum temperature needed for sowing.

The heating up and cooling down of the soil is also affected by the colour of the surface, as well as its coverage with crop residues or plants. Soil surfaces covered with crop residues are heated up slower in the spring due the usually lighter colour of crop residues and the resulting higher light-reflecting ability, as well as the higher moisture content and heat capacity of soils covered with crop residues. The shadowing effect of the crop cover decreases the heating up of the soil and the heat fluctuation, while it regulates the amount of energy reaching the soil surface. The more balanced soil temperature is rather favourable for soil-borne organisms, as the often repeating, high heat fluctuations block their activity and proliferation.

From the crop production aspect, the course of soil temperature during the year is an important topic. Soil temperature fluctuates in a day and also in a season. The value of heat fluctuation is the highest on the soil surface, since the heating up and the cooling down of the soil starts on the surface. The amplitude of heat fluctuation gradually decreased with the increase of depth, temperature is more balances in deeper layers. Daily heat fluctuation can be measured in the upper 60-80 cm layer of the soil; deeper layers only show seasonal fluctuation. During the daily heat fluctuation, the surface usually reaches its highest temperature at 2 p.m. and its minimum before sunrise. During the seasonal fluctuation, the temperature of the upper soil reaches its maximum in July and its minimum in February. The maximum value in the 100 cm depth is reached in August, while its minimum can be observed in February.

In the spring, the temperature of the seedbed could be a restraining factor in crop production, especially in the case of soils covered with crop residues. Under such circumstances, the soil reaches the optimum soil temperature needed by the sowing seed later and the delayed sowing could increase the yield decreasing effect of the dry summer period.

The factors which form the water, air and heat management of the soil are in close correlation with each other. It is the duty and also the opportunity of farmers to develop the proper pore system in order to establish the soil condition which meets the produced crops’ needs the most.
3. fejezet - 3. SOIL TILLAGE SYSTEMS OF FIELD CROPS

The definition of tillage system: The collective of cultivation procedures needed for the successful and economic production of one or more plants in a given area (consecutive series of procedure elements).

Factors determining the development of a tillage system:

- plant needs,
- production site circumstances,
- available agricultural machinery,
- soil protection duties,
- crop order,
- fertilisation and weed control systems.

Classification of cultivation:

1. Sowing date of the plant:

2.

- tillage system of late summer and autumn sown plants,
- spring sown
- secondary crops

3. Soil types: tillage guidelines of

4.

- Brown forest soils,
- Chernozem soils,
- Meadow soils,
- Alkaline soils and
- Sandy soils

5. Methods worked out by authors

6. New cultivation trends and systems

7. Special tasks

Classic order of soil preparation:

stubble tillage → primary tillage → secondary tillage → seedbed preparation → soil preparation after sowing

1. 3.1 Order of soil preparation

1.1. 3.1.1 Stubble-stripping
Stubble-stripping is a shallow cultivation (max. 10 cm) performed on the stubble (9. Figure). Aim of the stubble-ripping are as follows: reducing the moisture loss of the soil, weed control, controlling the heat cycle of the soil, increasing the biological activity of the soil, mixing the plant residues into the shallow soil.

Rules of stubble-stripping: it has to be performed immediately after harvesting, if possible compaction is needed in one turn with loosening, the treatment of the stripped stubble is necessary due to the appearance of weeds.

Equipment of stubble-stripping: tools suitable for loosening (disc, harrow, cultivator, rotary tiller) + compaction tool (roller)

3.1. ábra - Figure 9. Stubble-stripping

1.2. 3.1.2 Primary tillage (the deepest cultivation)

Aim of the primary tillage is the establishment the most suitable physical condition of the regularly cultivated soil layer until the end of the vegetation period.

Classification of primary tillage:

according to depth:
• shallow,
• medium deep,
• deep cultivation

according to rotation:
• with rotation (plough),
• without rotation: shallow, medium deep and deep loosening and combined methods.

Equipment of the primary tillage (10. Figure): plough, reverse plough, disc, cultivator, rotary tiller, medium deep and deep loosener, combined tools.

3.2. ábra - Figure 10. Equipment of the primary tillage

1.3. 3.1.3 Secondary tillage

Aim of the secondary tillage is the further developing the soil condition after the primary tillage in accordance with the need of the plant to be sown and the protection of soil.

Main requirements:
• the soil condition developed with primary tillage should not worsen,
• treading, dustification and the transfer of stubble residues to the surface should be avoided.
• weed control,
• reduction of moisture loss,
• helping seedbed preparation.

It can be done in one turn with the primary tillage or in a separate turn.
Equipment of the secondary tillage: disc, smoother, roller, cultivator, rotary tiller, rotary harrow, swinging harrow

1.4. 3.1.4 Seedbed preparation

Aim of the seed bed preparation is to adapt the soil condition established during primary tillage and its finishing to the sowing conditions (Figure 11). The proper seedbed has a small crumbly structure, it is settled, damp and free from weeds (Table 1).

The rules of seedbed preparation:

• Helps the sprouting and emergence of seeds or propagation materials (Figure 12)

• Improves the efficiency of herbicides and pesticides.

• It should include as little soil disturbing and dustification as possible.

• Loosening and crumbling until the planned depth and compaction below this depth.

Equipment of the seed bed preparation: combinator (cultivator + roller harrow), harrow + roller harrow, sowing cultivator, direct sowing machine.

3.3. ábra - Figure 11. Loosening, crumbling and compaction work of the combinator

3.4. ábra - Figure 12. Seedbed preparation shortcomings

3.5. ábra - Table 1. Field crops’ need for small crumbled soil structure in the seedbed

<table>
<thead>
<tr>
<th>Crop</th>
<th>Distribution of the soil fraction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-10 mm</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>60-70</td>
</tr>
<tr>
<td>Maize</td>
<td>60-70</td>
</tr>
<tr>
<td>Sunflower</td>
<td>60-70</td>
</tr>
<tr>
<td>Sugarbeet</td>
<td>70-85</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>80-85</td>
</tr>
<tr>
<td>Pea</td>
<td>60-70</td>
</tr>
</tbody>
</table>

1.5. 3.1.5 Finishing after sowing

Aim of the soil finishing is covering the seeds, pressing the soil to the seeds, compaction of the seedbed surface. It can be performed in one turn with sowing or in a different turn.
Rules of finishing after sowing:

- the sown soil has to be compacted,
- soil moisture and temperature has to be controlled,
- the soil surface has to be made suitable for emergence
- it should involve as little treading as possible.

2. 3.2 Tillage systems categorised by sowing date

2.1. 3.2.1 Tillage systems for late summer and autumn sown crops

Showing period of the late summer and autumn sown crops are last from 20th August until late October. Produced crops are rape, crimson clover, perennial legumes, winter barley, rye, winter wheat. The seedbed need of plants is more or less different. Crimson clover, alfalfa and rape need levelled seedbed with tiny crumbed structure, cereals need seedbeds whose structure contains crumbed fraction and walnut-sized clods in order to perform fast and steady emergence. The system determines whether the previous crop is harvested early or late.

Previous crops harvested late June and July are winter closed, flax, poppy, autumn and spring fodder mixes, pea, bean, winter and summer cereals. Mustard, oilseed radish, canary grass and hemp can be harvested early August.

Stubble tillage:

During stubble stripping and treatment, the soil should be gradually dustified. The aim is to perform shallow and mulch stripping which reduces the moisture loss of the soil. In order to perform gentle dustification of the soil, cultivator or flat disc dustified has to be used.

The primary cultivation can either be ploughing or without ploughing (Figure 13):

- Primary cultivation with ploughing = summer ploughing (moisture loss → closure is necessary): During summer ploughing, the soil can be tilled until the depth of soil ripening in order to be able to finish the soil surface effectively. Damp or moderately dry soil surfaces can be finished in one operation with ploughing with a tool mounted on or after the plough. On dry soil, this operation can be supplemented with clod-crushing or the elimination of hollowness. Moderately deep loosening is needed for the primary tillage of soil compacted at deeper layers.

- Primary cultivation without ploughing: Its main procedures are disc, cultivator and ripper cultivation, as well as moderately or deep loosening. Plants sown late summer and in autumn do not demand deeper primary tillage (with the exception of alfalfa). Loosening may be necessitated by soil protection or the elimination of harmful compactness.

3.6. ábra - Figure 13. Tillage systems of late summer and autumn sown plants after previous crops with short growing season
After late harvested previous crops, the system starts with stem crushing, followed by primary tillage with or without rotation (14. Figure).

Primary tillage with plough under winter cereals is only recommended in exceptional cases: lots of crop residues, strong infestation with weeds, moist soil, sloping production site, susceptibility to surface compaction.

The tool for primary tillage of autumn sown plants is the disc (several turns in various directions) or the heavy cultivator and medium-deep looseners. Disc tillage to a shallow depth in the first operation and until the planned depth in the second one, using also a clod-crushing roller. The seedbed can be prepared with a rotary combinator and a harrow, or in one operation with sowing (with the cultivation tools of the sowing machine). Heavy cultivators combined with soil surface finishing tools can be selected for the primary tillage of winter cereals for soil preservation purposes. Primary tillage with moderately deep looseners is especially reasonable in the case of compacted soil conditions. At the same time, care should be taken about the proper dustification of the upper soil layer.

Perennial legumes (alfalfa, red clover, cockshead, melilot and ley) are ideal previous crops of winter wheat. These crops leave behind vital stubble. There ploughing and non-ploughing methods available for breaking the stubble of perennials.

3.7. ábra - Figure 14. Tillage systems of late summer and autumn sown plants after previous crops with long growing season
2.2. 3.2.2 Tillage systems for spring sown crops

Sowing period is covered the March-April months.

Produced crops:

• ear cereals: winter barley, oat, rice
• root crops: potato, sugar beet, fodder beet
• pea, soybean, broad-bead, lupin
• oil crops: sunflower, oil flax
• maize

Two phases of soil preparation: autumn cultivation and spring cultivation. The system determines whether the previous crop should be harvested early or late.

After early harvested previous crops, the system follows the classic order (15. Figure).

Stubble tillage:

The stubble stripping has to be performed in accordance with the same cultivation- and quality-related aspects as in the case of autumn-sown plants.

Primary cultivation:

The primary cultivation could either be performed with or without rotation. Primary cultivation with rotation is called autumn ploughing. The majority of spring-sown plants develop the best on properly worked soils. Ploughing can be performed from late August until the first frosts on stripped and treated stubble or on loosened fields. Earlier ploughing needs to be carried out on steeper hillsides, low-lying areas, as well as on forest, meadow and alkaline soils that are difficult to cultivate.

The aim of autumn ploughing:

• helping the reception and storage of water,
• rotation and deepening of the regularly cultivated layer,
• incorporation plant residues,
• incorporation of farmyard manure.

The compacted soil conditions can be reduced with moderately deep loosening. The early harvesting leaves time for loosening.

The autumn ploughing has to be finished in the autumn to prepare it for early spring sowing, in the case of crumbly soil. However, the surface of soils which are wet in the autumn should not be finished.

Primary tillage without ploughing = medium deep and deep loosening. Soil condition providing the infiltration and storage of precipitation can be established with loosening. It can be used in dry autumn periods, in the case of previous crops with little stem residues, if there is a compacted layer.

During the spring tillage, the aim is to establish a non-dusty soil condition free from large clods with balanced moisture content. Seedbed can be prepared following the early spring drying on completely levelled soil which was cultivated in the autumn. The traditional tool for levelling is the smoother combined with spike harrow. Depending on plants’ needs, seedbed can be prepared with springy or spoon-spiked combinator, or a compactor which combines various cultivation tools.

3.8. ábra - Figure 15. Tillage systems of spring sown plants after previous crops with short growing season

![Diagram of tillage systems](image)

Tillage systems of spring sown plants after previous crops with long growing season:

If the previous crop was sugar beet, its crop residues have to be spread on the field before cultivation. The stem and root residues of maize need to be crushed with stem crusher, disc or both in order to improve the quality of soil work. The ripened or chemically defoliated sunflower stem can be easily crushed with a disc.

After late harvested previous crops the primary tillage can be carry out with or without rotation, combined tillage and sowing or direct drilling (16. Figure).

The omission of autumn primary tillage is not reasonable, with the exception sandy and soils that are highly exposed to deflation. If ploughing cannot be performed until the first frosts, it can still be done on winter days when there is no frost.

Primary tillage with plough can also be performed in the spring. Spring ploughing could be risky due to moisture loss and the unbalanced soil conditions concerning moisture and disintegration. Ploughing can be
3. SOIL TILLAGE SYSTEMS OF FIELD CROPS

performed in the spring if the soil surface can be finished in one operation. The disc finishing of the soil surface after spring ploughing should be avoided.

Primary tillage with plough must be performed in the spring:

• alkaline soils with no structure,
• flood areas,
• low-lying areas,
• quicksand, mull soils,
• if it cannot be performed in the autumn.

After late harvested previous crops, tillage and sowing in one single operation is another opportunity of the soil preparation for early spring-sown cereals.

3.9. ábra - Figure 16. Tillage systems of spring sown plants after previous crops with long growing season

2.3. 3.2.3 Tillage systems for secondary crop

Secondary crops are plants which are grown after the early harvested primary crop or before the primary crop. Summer secondary crops are sown after the primary crops are harvested in June or July.

The requirement of the successful production of secondary crops is the fast and high quality soil preparation with as little moisture loss as possible. Stubble stripping is not necessary since none of its functions can be used. Ploughing can be recommended only if sowing is performed the same day. As regards primary tillage, the shallow, no-tillage method with cultivator or disc is the most suitable solution. It is recommended to perform seedbed preparation and sowing in one operation.
4. fejezet - 4. Cultivation methods of different soil types

As a result of the geographical location, the basin character and climate of Hungary, the developed soil cover shows a very versatile character as seen in Figure 17. Main soil types from the aspect of field use: brown forest soils, chernozem soils, meadow soils, alkaline soils and marsh soils.

4.1. ábra - Figure 17. Situation of main soil types in Hungary

![Map of Hungary showing different soil types](image)

1. 4. 1. Brown forest soils

Zonally, brown forest soil is one of the most significant soil types. There are several subtypes of this soil which were formed as a result of the base rock, precipitation and the change of slope conditions. In Hungary, the range of brown forest soils is around 34.6%, mainly occurring on highlands, hilly areas and wooded peripheries of lowlands (Figure 18).

4.2. ábra - Figure 18. Situation of brown forest soils in Hungary
1.1. 4. 1. 1. Soil characteristics of brown forest soil affecting soil cultivation

The profile of brown forest soil is shown in Figure 19 where the light level “A” can be well distinguished from the darker level “B”. These characteristics are very different which basically determines cultivation.

4.3. ábra - Figure 19. Brown forest soil

- The soil profile usually is divided into leaching (A) and accumulation (B) levels.
- Level “A” is characterised by acidity, while level “B” has high clay content.
- The profile has unfavourable structure, it is compacted and its water reception ability is weak.
- The level “B” has the lowest water permeability.
• The surface is susceptible to siltation and crustiness which decreases the water reception ability of the soil and increases its airless character.

• Susceptibility to erosion.

• In sloping areas, the aim of cultivation is not only to establish a proper physical condition for the crops to be produced, but also to help the protection of the soil.

1.2. 4. 1. 2. Guidelines for cultivation of brown forest soils

Brown forest soils can be found mainly in sloped areas; therefore, erosion prevention is the main objective concerning its cultivation. The land use type has to be chosen depending on the slope angle. The direction of cultivation should always be perpendicular to the slope angle and parallel with the cleavage! The soil surface should never be smooth, because precipitation can flow down without any restraint towards the slope, carrying along the upper fertile part of the soil.

**Stubble-stripping:**

• On sloping soils rich in precipitation, shallow stubble-stripping increases erosion.

• In order to protect the soil and improve cultivability, mulch needs to be left on the soil.

• In rainy weather, unstripped stubble-field gives higher protection than if it is disturbed.

• Instead of shallow stubble-stripping, medium deep ploughing is more preferred, as a deeper soil layer becomes suitable for the reception of rainfall.

**Primary tillage:**

• More shallow primary tillage can be performed in areas where the compacted soil condition does not restrain the infiltration of water into the soil. Of the possible methods, the use of cultivators has the lowest risk.

• Moderately deep loosening has to be performed every 2–4 years on forest soils.

• As a result of the ploughing deeper then level A, the humus content of the cultivated layer decreases and unfavourable physical and chemical soil is mixed into the ploughed layer (Figure 20).

• Increased probability of the formation of the sometimes totally impermeable compacted layer.

• On sloping soils, primary tillage is one of the most important procedures of soil protection; the aim is to make the deepest possible soil layer suitable for the reception of large amounts of precipitation.

• On flat forest soils, the rules of ploughing are the same as that on chernozem soils.

4.4. ábra - 20. Figure Cultivation of brown forest soil
4. Cultivation methods of different soil types

- ploughing (rotation) can only be performed until the depth of the leaching level “A”,
- the deepest loosening tillage has to be performed until the depth of level “B”,
- level “B” has to be loosened, as it blocks the downward motion of water,
- the most effective tool of loosening is the deep loosener,
- level “C” usually has good water intake characteristics

Secondary tillage:
- The primary tillage should not be finished on areas that are rich in precipitation and exposed to erosion.
4. Cultivation methods of different soil types

- In order to maintain the soil protection effect of ploughing, the soil should be left open.
- If finishing is necessary, it can only be done by creating a rough surface.
- Each cultivation process and sowing have to be performed perpendicularly to the slope direction, the creation of a smooth soil surface has to be avoided.

Seedbed preparation, sowing:
- A proper crop density also provides a good soil protection effect.
- Finishing and seedbed preparation can be done in one turn.
- After sowing, profiled surface should be established for protection purposes.
- On forest soils in need of protection, maize and sunflower can also be produced with strip tillage or even direct sowing.

2. 4. 2. Chernozem soils

Chernozem soils are mostly moderately plastic clay soils on the best plough lands of Hungary. Zonally, the second most significant soil type is chernozem in Hungary. In the Great Plain regions, chernozem soil developed on loess deposits as a result of continental climate under forest-steppe vegetation (Figure 21). Area: 22.4%, mostly on higher parts of lowlands.

4.5. ábra - Figure 21. Situation of Chernozem soils in Hungary

2.1. 4. 2. 1. Soil characteristics of chernozem soils affecting cultivation

There are several known subtypes of chernozem soils. Various subtypes were formed depending on the grain composition of the base rock, the amount of precipitation, the terrain configuration and the impact of groundwater. Leached chernozem in rainy areas, calcareous chernozem on loess base and calcareous Great Plain chernozem on high silt content base rock. Due to the hydromorphic effect, deeply salty calcareous Great Plain chernozem, deeply salty meadow chernozem and meadow chernozem soils were formed (Figure 22).
4. Cultivation methods of different soil types

4.6. ábra - Figure 22. Main characteristics of calcareouschernozem soil

- Good humus and Ca supply, crumb structure.
- The water reception and air management of the soil is usually favourable in the whole profile.
- As a result of inadequate cultivation, the deterioration of the ploughed layer and its inclination to compaction can be rather significant.
- Usually, there is a rather compacted layer below the ploughed layer.
- Erosion and deflation processes can also damage the soil.

4.7. ábra - Figure 23. Water erosion on chernozem soil

2.2. 4. 2. 2. Guidelines for chernozem soil cultivation

The main guiding principle is the maintenance of the favourable characteristics of chernozem soils and the reduction of harmful circumstances. The soil structure needs to be preserved and the number of turns have to be as few as possible, while moisture preserving cultivation methods need to be worked out. The natural loosened condition and porosity of the soil created favourable conditions for the development of crops.
4. Cultivation methods of different soil types

Stubble-stripping

• One of the most important procedures of moisture-saving cultivation, its aim is to help the sprouting of weeds,

• if possible, it has to be performed immediately after the previous crop is harvested.

• The stubbles of the moderately plastic clay soils free from extremities are recommended to be stripped with either cultivator combined with a closing tool or with a flat disc dustifier.

• Stem crushing makes cultivation and the incorporation of field residues into the soil easier.

Primary tillage

• It can be carried out either with ploughing or without ploughing.

• If there is no disqualification, shallow loosening and crumbling are the proper forms of primary tillage in the case of crops sown in the late summer and autumn.

• Ploughing is needed in the autumn for crop protection purposes and in the case of spring root crops.

• One of the important basic requirements of the successful production of crops sown in the spring is autumn ploughing.

• Under low-rainfall circumstances, cultivation without ploughing has to be preferred.

• The depth of tillage is determined by the soil humus content, structural condition and moisture contents, as well as the need of the crop to be produced.

• Deep cultivation is needed if there is a layer which blocks root development (lime barrier, compacted layer).

• It might be needed to take care of the harmful tillage-pan by performing periodical deep cultivation every 4 years (e.g. by increasing the depth of ploughing by 6-8 cm).

• In the case of irrigated soils, the water infiltration ability of soils has to be increased with loosening.

Seedbed preparation, sowing:

• In the case of plants sown late summer and autumn and spring cereals, the single-operation method of seedbed preparation and sowing is recommended.

• In other cases, separate operations are more suitable, but the number of operations can still be reduced rationally.

3. 4. 3. Meadow soils

The high groundwater level is the main causes of the formation of meadow soils. Area: 13.1%, they can be found in lower parts of lowlands, the alluvial plains of rivers, in valleys of hilly areas and highlands and between sand-hills (Figure 24).

4.8. ábra - Figure 24. Situation of meadow soils in Hungary
3.1. 4. 3. 1. Soil characteristics affecting the cultivation of heavy meadow soil

4.9. ábra - Figure 25. Main characteristics of meadow soil

- high organic and inorganic colloid content,
- high water storage capacity, unfavourable water conduction,
- airless conditions due to the saturation and compactness,
- high swelling and shrinking ability,
- the soil is heated up slowly, which is a disadvantage in the spring and an advantage in the spring
- the groundwater close to the surface blocking the root development is frequent, as well as the saturated zone until the capillary water capacity, quick saturation after rains,
4. Cultivation methods of different soil types

- high groundwater level in the spring, drainage wateriron pan, lime barrier and gley; salt accumulation in the Trans-Tisza region,
- narrow moisture limits of cultivability

3.2. 4. 3. 2. Guidelines of the cultivation of heavy meadow soils

Aim of cultivation reducing the effect of unfavourable soil conditions and the improvement of cultivability.

Tillage mistakes increasing the unfavourable soil characteristics:
- Development of a compacted soil layer under the cultivated depth.
- Drying and clodding of the upper layer of the soil.
- Stamping, smearing, treading the soil
- Organic matter loss, more difficult cultivability.
- Increasing weed coverage.

Cultivation methods easing the unfavourable soil characteristics in the case of heavy meadow soils:
- Improving the water infiltration and preservation ability with loosening.
- Prevention of siltation and crustiness with surface coverage in the summer.
- Disturbing only in the case of proper moisture content.
- Various cultivation depth and proper selection of the tillage method.
- Returning the organic matter into the soil, prevention of weed expansion.

Stubble-stripping:
- After the summer harvest, heavy meadow soils are usually in dry and compacted conditions and the stubble stripping can only be performed if the soil contains enough moisture.
- During stripping, the disc or the cultivator has to operate at a shallow depth and the surface needs to be finished with a clod-crusher roller.
- Under wet circumstances, with roller and heavy or plain disc harrow.
- Performing shallow stubble-stripping which leaves mulch on the soil surface is more favourable.

Primary tillage:
- In the case of plants sown late summer and autumn, primary tillagewithout ploughing (with disc or cultivator) is recommended after early harvested previous crops.
- On meadow soils, medium deep loosening should be used more frequently.
- Summer ploughing is mostly not advised due to the questionableness of finishing.
- If possible, autumn ploughing should be performed in the case of favourable moisture content.
- The maximum tillage depth with plough could be the layer of level “A” which contains the most humus,
- The deep cultivation of the soil aims to eliminate compaction and the airless character of the soil,
- All of these operations have to be performed in a way that the harmful layers do not come to the surface.

Deep cultivation:
4. Cultivation methods of different soil types

- The deep loosening of the soil should be the deepest possible, the compactness and airless character should be ceased and the water reception ability has to be improved.

- It is a very important requirement of deep loosening that the soil be as dry as possible because of the high organic and inorganic colloid content and swelling ability.

- In the case of the deep cultivation of a wet soil, the desired cracking impact will not be achieved; the duration of the effect of deep cultivation will be significantly shorter.

Secondary tillage, seedbed preparation

- Due to seedbed shortcomings, soils whose moisture is higher than what is acceptable for cultivability are not recommended to be finished.

- Attention must be paid to the fact that the furrow splitter of the sowing machine and the compactor element of the seedbed preparation machine should not smear the soil in the depth of sowing.

- If the seedbed preparation and sowing are done in one turn, good sowing conditions can be established on still crusty, but evenly finished soils.

- After sowing, the crustiness of the soil can be prevented by establishing a profiled surface.

4.4. Alkaline soils

The main causes of the formation of alkaline soils are the high salt content groundwater close to the surface and the salt accumulation as a result of strong evaporation. Area: 6.5%, in the Danube-Tisza mid-region, in saltwater depressions, in the Hortobágy, in the area of the Kőrös rivers and some regions of the Kisalföld and the Nyírség areas (Figure 26).

4.10. ábra - Figure 26. Situation of alkaline soils in Hungary

4.1. Soil characteristics of alkaline soils affecting cultivation
Alkaline soils can be characterised by extreme water and nutrient management, high nutrient capital, small available nutrient stock and difficult cultivability. The range of plants which can be grown is limited and there is a high yield fluctuation. As a result of chemical soil improvement, the productivity and the yield improve, but it has no effect on the reasons for salinification. The chemical problems are increased by the impacts of physical soil imperfections (quick deposition, compaction, cloudiness in dry conditions) and it is also true the other way round. The most important characteristic of the alkaline soil (27. figure) is the presence of sodium salts in the soil solution or as ions on the surface of colloids:

4.11. ábra - Figure 27. Main characteristics of alkaline soil

- In many cases, all these are coupled with clay content, the physical, chemical and colloidal characteristics are rather unfavourable,
- compacted, airless
- large extent of swelling and shrinking,
- weak water reception ability,
- as a result of sodium salts, water causes the soil to become runny, while in the case of dryness, clods will be formed that are difficult to break.
- The aim of cultivation is to ease the effect of extreme soil characteristics and to maintain moisture cycle and cultivability as much as possible
4. Cultivation methods of different soil types

- The cultivability of alkaline soils is low, their resistance is high.
- The moisture interval of cultivability is narrow (minute soil).
- Cultivation performed in their wet state can damage the soil structure for years.
- Meadow solonetz soils, meadow steppe-solonetz soils, chernozem under secondary salinification, meadow and alluvial soils are suitable for plant production.

4.2. Guidelines for soil cultivation of alkaline soils

The aim of cultivation is the reduction of the effect of extreme soil characteristics and the maintenance of moisture cycle and cultivability.

**Stubble-stripping:**

- It can only be performed on wet soils, the soil is still rather compacted; therefore, only heavy disc harrow can be used.
- The moisture preservation role of stubble-stripping does not prevail.

**Primary tillage:**

- Soil should be tilled only until the depth determined by the soil analyses.
- Deeper tillage results in layers with higher salt content come to the surface which further deteriorates the fertility and cultivability of the soil.
- The only possible method of deep cultivation is deep loosening.
- Every type of cultivation – including deep loosening – should be done within the optimum moisture limit values.
- If this is not possible, the soil has to be cultivated in a condition which is dryer than the optimum moisture limit value.
- In most cases, the cultivation of wet soils is impossible because of the movement problems of the machines.

**Secondary tillage, seedbed preparation**

- Since the inclination of the soil to siltation is rather high, it is not recommended to finish the area to a smooth texture after the autumn ploughing.
- In the spring, the upper layer of the soil is usually wet and compacted, no smoother or cultivator can be used.
- The machine used in the spring tillage is the disc harrow and the heavy grub-crusher roller.
- The seedbed has to be left slightly crusty, because the soil will become runny as a result of rain and crops cannot break through this layer.
- After sowing, it is recommended to establish a profiled surface.

5. Sandy (skeletal) soils

The base rock, precipitation, wind and the plant cover influence the soil formation process in areas covered with sand. Sand drifts are formed in areas more exposed to wind, while humid sandy soils are typical in less exposed regions. Calcareous sandy soils can be found in the Danube-Tisza mid-region and non-calcareous sandy soils in the Nyírség and Somogy areas (Figure 28).

5.1. Soil characteristics of sandy soils affecting cultivation
4. Cultivation methods of different soil types

4.12. ábra - Figure 28. Situation of sandy (skeletal) soils in Hungary

- Light mechanical composition.
- Small amount of inorganic and organic colloids.
- Unfavourable water management and water preservation ability.
- They are easier to cultivate, but inclined to deflation.
- The composition and thickness of their fertile layer are heterogeneous.
- The number of crops which can be safely produced is low and the yield fluctuates.

4.13. ábra - Figure 29. Soil characteristics of sandy soils

5.2. 4. 5. 2. Guidelines for soil cultivation of sandy soils
The aim of cultivating skeletal soils is to improve production safety, to reduce the unfavourable soil characteristics and to prevent deflation damages. Two groups can be formed from the aspect of soil preserving cultivation (Westsik): quicksand and humic sandy soils.

Guidelines of soil cultivation in the case of quicksand soils

- Stubble-stripping can only be done in exceptional cases, the soil protection role of weeds and the sprouted plants from scattered seeds should be exploited,
- One of the most important basic principles of the cultivation system is that the produced crops should cover the soil surface as long as possible.
- Loose soils are protected in their stubble conditions or with mulch stripping.
- If there is a short amount of time between harvesting and sowing the next plant, it is recommended to perform moderately deep ploughing and to close the surface immediately with a combined roller.
- The stubbles of late harvested plants should be covered with crushed crop residues and mulch before the winter.
- Ploughing or no-tillage cultivation should be done directly before sowing.
- The seedbed for crops to be sown in the late summer or autumn should be prepared with the least disturbing. The spring primary tillage of spring sown crops has low risk.
- After sowing, a wavy soil surface has to be established.
- The period under which the soil surface is not protected by plant residues or crops should be reduced to the minimum.
- Due to the settling of quicksand soils, the loosening has to be performed deeper than the usual primary tillage.

Guidelines of cultivating humic sandy soils:

- In the case of humic sandy soils, there is a lower deflation risk and its duration is also shorter, but the deflation damage caused by spring winds could still be significant.
- The characteristics of humic soil are rather favourable from the aspect of cultivation.
- The stubble-stripping can be performed without the increase of deflation risk.

Primary tillage of humic sandy soils:

- Under wet circumstances, plough is the tool of primary tillage.
- Under dry circumstances, primary tillage can be carried out with no-tillage loosening.

Secondary tillage, seedbed preparation

- Usually no large crumbs are developed after the primary tillage,
- It can be performed with a few turns.
- In order to reduce the damage done by evaporation by means of water loss, erosion and deflation, the soil has to be disturbed as little as possible.
- The loosened soil has to be properly compacted as quickly as possible.
- In soils exposed to deflation, a wavy soil surface has to be developed and efforts must be made at maintaining a plant coverage on the soil for the most part of the year.
- The deep cultivation of the soil is only necessary in the case of a compacted layer.
6. 4. 6. Marsh soils

Marsh soils were formed under marsh forests. 1.5% of Hungary’s area are marsh soils. Characterised by constant over-wettening. Hanság, Nagyberek, Kis-Balaton, Ecsed bog, Nagysárrét.

6.1. 4. 6. 1. Characteristics affecting the cultivability of the marsh soils

- Containing more than 20% organic matter.
- The dead plant residues become peaty due the lack of air.
- With the decrease of water level, the humification process of the peat starts.
- Marsh soils are fertile and rich in nitrogen, P and K replenishment is necessary.
- High wilting point, artificial water replenishment is needed,
- The proper depth of groundwater has to be maintained (water control).

6.2. 4. 6. 2. Guidelines for soil cultivation of marsh soils

Mull soils are suitable for field cultivation. Short rotation crops are recommended to be grown. Machines with low soil pressure can be used in cultivation (rubber band, side-by-side wheel). The soil becomes overgrown with weeds strongly.

Stubble-stripping:

- Its main goal is to help the sprouting and the killing of weeds,
- Shallow cultivation tools with good weed control features can be used, (cultivator equipped with goose sole-shaped knives)
- Roller has to be used after each activity.

Primary tillage:

- Due to the high deflation risk, the autumn ploughing has to be omitted.
- Spring ploughing or disc harrowing is necessary in order to help evaporation and the heating up of the soil.
- Each loosening cultivation activity has to be followed by compacting (marsh roller=heavy smooth roller).
- Each cultivation activity has to be performed perpendicularly to the prevailing wind direction.
5. fejezet - 5. Conservation tillage systems

The most topical problem of cultivation around the world is the deterioration of the condition of soils. The main task of new cultivation systems is the reduction of soil degradation and the improvement of soil conditions. The tillage systems used today can be classified the following way: conventional tillage, reduced tillage, minimum tillage, conservation tillage etc.

1. 5.1 Characteristics of conventional tillage systems

Traditional, or conventional, tillage refers to the sequence of operations most commonly or historically used in a given field to prepare a seedbed and produce a given crop. Conventional tillage, which varies widely among regions incorporating most crop residue and leaving less than 30 percent of the surface covered by residue after planting.

The main characteristics of the conventional tillage systems in Hungary:

- the tillage of the entire surface is done with a plough
- soil surface exposed to erosion and deflation free from crop residues (Figure 30.)
- typically, this system consists of a high number of passes
- the soil condition needed by crops is achieved by using higher time and energy consumption than what would be rational.

Conventional tillage systems accompanying phenomena on soil condition are the degradation and/or compaction of soil structure, reduction of the organic matter content, water erosion and deflation. Despite the high time, living labour and fuel needs, the proportion of areas on which conventional tillage is use is rather high in Hungary. The main reason for the frequent use of conventional tillage are the power of traditions, little need to learn, available traditional tillage equipment, ease of incorporation the crop residues into the soil and controlling weeds, pathogens and pests.

Compared with conventional plowing systems, the conservation tillage reduce the number of tillage operations or passes, the amount of diesel fuel that is used, the amount of dust that is generated, and the volume of soil that is disturbed. For this reason, the term “conservation tillage” is justified in characterizing them.

5.1. ábra - Figure 30. Conventional tilled soil surface
2. 5.2 Characteristics of minimum tillage system

The tendency of minimum tillage was established in the USA in the 1950s. It refers to systems that reduce tillage passes and thereby conserve fuel for a given crop by at least 40 percent relative to what was conventionally done. This term defines a standard that is based on achieving the 40 percent or more reduction in the number of tillage or soil-disturbing passes. Advantages of the technique include reductions in energy consumption by farm equipment, less soil erosion, and lower soil moisture losses during the fallow season. Disadvantages include the possibility of encouraging insect pests by leaving the crop residue in the field and the use of herbicides to control weeds in the place of mechanical cultivation.

3. 5.3 Characteristics of reduced tillage system

Since the early 1960s, the term “reduced tillage” has generally referred to any tillage system that is less intensive and that employs fewer trips across a field than traditional tillage. Reduced tillage is maintaining at least 15 percent but less than 30 percent coverage by surface residue after planting. Reduced tillage practices have tremendous potential to reduce farmer expenses, maintain yields, and reduce potential negative environmental effects caused by cropping operations.

4. 5.4 Characteristics of conservation tillage systems

Conservation tillage was defined in 1984 by the U.S. Soil Conservation Service as “any tillage system that maintains at least 30% of the soil surface covered by residue after planting primarily where the objective is to reduce water erosion”. When wind erosion is a concern, the term refers to tillage systems that maintain at least 1,120 kg/ha of flat “small-grain residue-equivalents” on the soil surface during critical erosion periods. The term “conservation tillage” broadly encompasses tillage practices that “reduce the volume of soil disturbed” preserve rather than incorporate surface residues; and “result in the broad protection of soil resources while crops are
grown”. Because of the importance of surface residues to this early definition of conventional tillage, now uses the term “crop residue management” rather than “conservation tillage” in their inventories of conservation practices. Five categories of conservation tillage system in North America are as follows: no-tillage, slot-planting, strip-tillage, ridge-tillage, and mulch-tillage as types of conservation tillage.

4.1. 5.4.1 No-tillage or direct seeding

Tillage is essentially eliminated with a no-till system. No-till is also referred to as zero-till. In no-tillage or direct seeding systems, the soil is left undisturbed from harvest to planting except perhaps for injection of fertilizers. Soil disturbance occurs only at planting by coulters or seed disk openers on seeders or drills (Figure 31.). Tilling only a narrow slot in the residue-covered soil achieves excellent erosion control. Shredding standing crop residue prior to planting is not recommended in no-till systems. Performance of planters, drills and cultivators is improved when the residue is standing and attached to the soil, rather than when unattached and lying flat. Although weed control is essential to all systems, the lack of tillage for incorporation with no-till requires preemergence, surface applied or post emergence herbicides. One or two properly timed applications may be necessary. In some poorly drained soils covered with large amounts of residue, the use of no-till may delay soil warming and drying in the early spring, which delays germination and emergence. When colder and wetter soils are of concern with early planting dates, the use of no-till planter attachments designed to move only residue and not soil away from the row have proven successful.

Compared with the no-tillage systems, conservation tillage systems that reduce or combine passes do so generally with relatively high amounts of soil disturbance, and therefore do not protect the soil resource as well as do the no-tillage or strip-tillage approaches.

Advantages of no-till:

• Maximum erosion control.
• Soil moisture conservation.
• Minimum fuel and labor costs.
• Input and equipment costs are lower than other tillage systems.
• Soil erosion by wind, water and tillage is greatly reduced.
• Labor inputs per hectare are greatly reduced.

Disadvantages of no-till:

• No incorporation.
• Increased dependence on herbicides. Weed control is largely dependent on herbicides.
• Not well suited for poorly drained soils.
• Initially high residue levels can slow soil warm-up.
• Attachments, such as coulters, must be added to planters and drills.
• High management level is required.
• Manure incorporation is difficult.

5.2. ábra - Figure 31. No-tillage
5. Conservation tillage systems

4.2. 5.4.2 Slot-planting

Slot-planting. It can be regarded as the advanced version of the no-till system. In one operation with sowing, a deep slot is formed under the sowing line, thereby loosening, then recompacting the soil.

4.3. 5.4.3 Strip-tillage

With strip-tillage, the seed row is tilled prior to planting to allow residue removal, soil drying and warming, and in some cases subsoiling (Figure. 3). Strip-tillage as systems in which less than one-third of the soil surface is disturbed.

Advantages of strip-tillage:

• Soil erosion by wind, water and tillage is reduced.
5. Conservation tillage systems

- Soil moisture conservation.
- Low fuel and labor costs.
- Tilled residue-free strip warms quickly.
- Injection of nutrients into row area.
- Well suited for poorly drained soils.

Disadvantages of strip tillage:

- Special tillage equipment required.
- Strips may dry too much, crust, or erode without residue.
- Timeliness in wet falls.
- Possible RTK guidance cost.

5.3. ábra - Figure 32. Strip tilled soil surface
4.4. 5.4.4 Ridge-tillage

In ridge-tillage, the soil is also generally undisturbed from harvest to planting except for fertilizer injection. Ridge tillage systems plant crops on raised ridges. Crops are seeded and grown on ridges or shallow beds that have been formed or built during the prior growing season, generally during cultivation using implements fitted with sweeps, hilling disks, and furrowing wings. Ridge-tillage planters employ sweeps ahead of the seed or planter shoe that effectively shear off soil and residues from the surface of the ridge, creating a clean seed row (Figure 33.). Weed control is accomplished by herbicides, cultivation, or both. Ridge till planting better used in heavier soils that are slow to warm. Ridge has warmer soil, dries sooner, and warms faster. Better emergence and better mineralization of nutrients.

Advantages of ridge-tillage:

- Excellent erosion control if on contour.
- Well adapted to poorly drained soils.
- Excellent for furrow irrigation.
- Ridges warm up and dry out quickly.
- Low fuel and labor costs.
- Soil is protected from wind and water erosion, and erosion due to tillage is reduced.
- Controlled traffic reduces compaction in the crop rows.
- Inter-row cultivation and ridging operations control weeds.

Disadvantages of ridge-tillage:

- No incorporation.
5. Conservation tillage systems

• Creating and maintaining ridges.
• Narrow row plants and small grains not well suited.
• Inter-row cultivation is required to rebuild ridges.
• Ridges must be levelled before forage crops can be grown.
• Wheel spacing of all machinery must be modified to avoid driving on ridges.
• Manure incorporation is difficult.

5.4. ábra - Figure 33. Ridge tillage

Source: http://corn.agronomy.wisc.edu/Management/images/L007/tillage.gif

4.5. 5.4.5 Mulch tillage

Mulch tillage includes any conservation tillage system other than no-tillage, strip-tillage, or ridge-tillage that preserves 30 percent or more surface residues. Mulch-tillage uses conventional broadcast tillage implements such as disks, chisel plows, rod weeder, or cultivators, but with limited passes across a field so as to maintain plant residue on the soil surface year-round. This was probably the earliest approach to conventional tillage system, and it dates back to 1930 when the first chisel plow was used. Mulch tillage is also referred to as reduced tillage, minimum tillage or conservation tillage.

Advantages of mulch tillage:
• Soil erosion and water runoff are reduced.
• Input costs are lower compared to conventional tillage.
• Many of the advantages of conventional tillage are maintained.

Disadvantages of mulch tillage:
• Planter modifications may be required.
• Soil warming in the spring can be slower due to crop residues.
• Primary tillage may not be effective under wet soil conditions.
• A larger tractor may be required for primary tillage.

5. 5.5 Western Europe type tillage systems

In Western Europe, tillage systems are classified into three groups: conventional, reduced, and no till systems (Figure 34.). In all three groups, the main objective is the protection of soil which can be fulfilled to various extents, depending on the given crops. The farming and cultivation systems used in Western Europe have been affected by the diversity of production sites, as well as the endeavours for the constant development of the technical level and for the rational economicalness from the 1970s. The variations are described below:

• Conventional tillage systems: the tillage of the whole surface is performed with a plough (reversible plough). The various operational steps are performed in different operations, usually one operation per step for which modern tools are at disposal. The total number of operations is 3-5 in this tillage system, depending on the given crops. In the improved alternative of the traditional tillage system, the whole soil surface is cultivated, ploughing is used as primary tillage (reversible plough) every year or every 2-3 years. Secondary tillage, seedbed preparation, sowing and surface finishing after sowing are performed in one operation with a machinery combination constructed especially for this purpose. Periodical soil loosening in compacted areas. The total number of operations of this cultivation system is 1-3.

• Reduced tillage systems: using combined heavy cultivators, heavy discs or loosener/rotary tiller combinations for primary tillage in years between ploughings (in one operation with sowing in some cases). Secondary tillage, seedbed preparation and sowing are usually performed in one operation, with one combination. The number of operations of this cultivation system is 1-3.

• No-till: Disturbance affecting not more than 10% of the soil surface. Mainly in dry areas and areas prone to drought, as well as in areas to be protected. The total number of operations is 1-2.

5.5. ábra - Figure 34. Tillage systems in Western Europe

Source: http://corn.agronomy.wisc.edu/Management/images/L007/till.gif

6. 5.6 Tillage systems comparisons

The most important advantage of conservation tillage systems is significantly less soil erosion due to wind and water. Other advantages include reduced fuel and labor requirements. However, increased reliance may be placed on herbicides with some conservation tillage systems. The moldboard plow system has the greatest fuel and labor requirements for tillage and planting. Continued use of a no-till or ridge system has resulted soil structure improvement, organic matter accumulation. With limited soil moisture, all conservation tillage systems out-yield systems which have intensive tillage. This occurs because tillage results in moisture losses, and conservation tillage both reduces the amount of tillage and leaves residue on the soil surface, further reducing evaporation and runoff.

Regardless of the tillage system selected, residue should be uniformly spread behind the combine using either a straw chopper or straw spreader. Uniform distribution of residue and chaff reduces equipment clogging, and provides more uniform soil conditions for planting, easier weed control and better erosion control (Table 2).

5.6. ábra - Table 2. Comparison of different tillage systems
### 5. Conservation tillage systems

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6. fejezet - 6. The necessity, method and tools of deep tillage

1. 6.1. Cause and significance of soil compaction

Of the processes endangering the condition of soils, physical degradation (compaction and structural deterioration) became a worldwide problem. 83.3 million hectares are affected by some form of physical degradation around the world. In Europe, the size of physically degraded areas is 36.4 million ha, 33.0 of which is affected by soil compaction. According to certain researchers, the size of Hungarian land that can be considered compacted is 1.2 million ha, others claim it is 3.1 million ha.

Soil compaction is the artificially developed deformation of soil structure that is accompanied by the reduction of porosity and (air, heat, water) permeability of soil and the increase of its penetration resistance (BIRKÁS et al., 1996b). Soil compaction can also be elicited by natural factors, but it is most often caused by human activities.

The physical degradation and compaction of soil can be a result of both natural and human factors, but the main cause is mechanisation and unprofessional cultivation. In the recent decades, the high power and heavy machinery used in agricultural significantly contributed to the development of increasingly thick compacted layers. Nearly all agrotechnical operations are the result of mechanical power. The traditional soil preparation in a cultivation technology typically consists of several operations. Mechanical combinations consisting of a lower number of operations are less frequently used. The deep tillage soils is neglected due to aspects of economicalness, while the tillage system based on primary tillage performed at the same depth for several years has become widespread, causing severe compaction in the topsoil in the first years.

The factors eliciting soil compaction can be divided to external and internal impacts. External impacts include structure degradation due to natural causes, machinery and tillage equipment. The most significant factors of the internal powers acting within the tri-phase system of soil are swelling-shrinking and freezing-melting. The swelling-shrinking resulting from the wetting and shrinking of compacted layers loosens the soil and increases the volume mass of loose layers.

Natural causes: the lack of soil structure developing and stabilising materials (inorganic and organic colloids, cementing materials, biological components) and the natural structure degradation (high intensity showers, surface runoff, water inundation, change of chemical characteristics).

Anthropogenic causes: using high heavy machines, tillage under improper moisture circumstances, high number of operations, tillage of the same depth, inadequate setting of the cultivation tool, improper soil moisture regulation, unfavourable change of the organic matter cycle of the soil.

Based on the location of compaction, it can be classified as surface or near-surface compaction (wheel-track, cultivation tool), as well as subsoil compaction that is mostly elicited by natural factors (soil formation processes, groundwater) (Figure 35-36).

6.1. ábra - Figure 35. Soil compaction caused by anthropogenic factors on the surface (wheel-track) and by cultivation tools
6. The necessity, method and tools of deep tillage

6.2. ábra - Figure 36. Soil compaction caused by tillage equipment
High number of operations and procedures carried out under improper moisture circumstances are among the most frequent causes of soil compaction. The compaction and soil structure degradation impacts of machinery movements on wet soil are high; therefore, this form of the physical degradation of soils is a great problem in countries which have wet climate.

### 2. 6.2. Factors influencing soil compaction

The resistance of soil towards external, mechanical loads is determined by its strength (consistence). If the mechanical load outweighs the soil strength, the pore space of the soil will be reduced (due to the practical incompressibility of the solid soil constituents). The soil particles will get closer to each other and they will have connection with each other on a larger surface and their spatial arrangement will change. The main characteristics determining soil strength are moisture content and moisture potential, grain and clay mineral composition, the amount and composition of exchangeable cations, organic matter content, volume mass, distribution and continuity of pores by size. Of these characteristics, moisture content and grain composition have the most important role, soil strength decreases with increasing moisture content within a certain range (Figure 37.). In the case of moisture content with nearly maximum water saturation, the soil can be compressed until it reaches the saturated condition. After this point, mechanical load does not cause any significant increase in volume. Therefore, the compressibility greatly depends on its consistency. Soils dryer than the plasticity limit can hardly be compacted, while wet and more plastic soils can be compacted significantly. The resistance of soils containing both coarse and fine grains towards compaction powers exceeds that of soils which have mechanical composition where a given grain fraction size is dominant.

Boekel’s “B” index can be used to characterise soils’ sensitivity to compaction powers. This value is the ratio of the plasticity limit and the field capacity of the soil. The closer the B index is to 1, the more resistant the soil is to compaction. Values around 0.5 are typical of soils which are most sensitive to compaction. MÁTÉ (1996) calculated the B indexes of certain Hungarian soil types and got the following values: chernozem: 0.96, brown forest soil: 0.80, meadow soil: 0.81, solonetz: 0.59.
SOANE and Ouwerkerk (1994) used a three-group classification of soils, based on the physical degradation caused by compaction, as well as the degree of compaction. At the weak compaction level, the unfavourable soil condition can be stopped with tillage. At the moderate level, meliorative methods can still improve soil conditions, while strongly compacted soils cannot be used for agricultural production purposes.

Várallyay and Leszták (1989) prepared a category system expressing the sensitivity of Hungarian soils to physical degradation. They set up eight categories based on the genetic type and subtype of soils, as well as their acidity and lime conditions, physical soil types, water management characteristics, organic matter stock and the thickness of the soil layer:

- sandy soils not sensitive to compaction and structural degradation,
- soils slightly sensitive to compaction and structural degradation,
- soils moderately sensitive to compaction and structural degradation,
- structureless sandy soils sensitive to compaction,
- soils with heavy mechanical composition which are sensitive to compaction and structural degradation,
- soils sensitive to compaction and structural degradation due to salt accumulation and/or salinisation,
- organic soils,
- soils with shallow fertile layer.

### 3. 6.3. Consequences of soil compaction

As a result of compaction, the volume mass and penetration resistance of soil increase, while its porosity, air supply and water conduction ability decrease (Figure 38.). As a consequence of compaction, the arrangement of
pores by size also changes. During the determination of the pF curve the soil sample taken from the compacted layer of the adobe soil retains less water in the case of low suction pressure and more water if there is more suction pressure which relates to the decrease of the proportion of macropores and the increase of the quantity of capillary pores. Depending on the extent of compaction powers, the pore size between aggregates of dry soil decreases, but the aggregate porosity changes only slightly. On wet soil, the spatial arrangement of soil particles forming the aggregates can change depending on the extent of the power.

6.4. ábra - Figure 38. The impact of compaction on the moisture and air cycle of soil

The soil is considered to be severely compacted if the soil resistance measured with a penetrometer exceeds 3-3.5 MPa and the volume mass exceeds 1.5 g/cm³ (BIRKÁS, 1994). The volume mass of sandy soils in a strongly compacted condition reaches 1.7-1.8 g/cm³ (FEKETE, 1996).

A compacted soil layer blocks the growth of plant roots (Figure 39.). Soil compaction increases the damage done by drought. On compacted soil, roots develop in a shallow soil layer; therefore, a relatively more notable yield reduction can be expected in drought years. Different crops react to soil compaction differently. Sugar beet, soy and maize are especially sensitive, while cereals are less sensitive. Maize is mainly sensitive to near-surface compactedness and the most favourable soil condition is if the soil is adequately loose until at least 40 cm depth and there is no plough pan in this layer (BIRKÁS, 1995).

Soil compaction affects the availability of plant nutrients indirectly due to the change in the air supply and water management characteristics of the soil, as well as the speed of material flow towards the crop roots. The indirect impact on the nutrient uptake of crops is shown through the change of the spatial distribution of the root and the root-soil correlation. As a result of the slow mineralisation of nitrogen and the increasing denitrification processes in compacted soils, the amount of available nitrogen could significantly decrease. Phosphorus and potassium are less mobile in the soil; therefore, their availability depends on the speed of root growth. The compacted soil layer blocks root growth and it has an adverse effect on the phosphorus and potassium supply of plants.

6.5. ábra - Figure 39. Soil compaction blocks root growth
Consequences of soil compaction:

- the air permeability of the soil is terminated or slowed down,
- the water reception ability and the water permeability deteriorate,
- the useful biological processes of the soil slow down,
- the water and nutrient uptake of crops is becoming limited,
- the compacted layers block the root growth,
- increased risk of drainage waters,
- the effect of fertilisers and chemical substances becomes unpredictable,
- as a result of the slow development of plants, their disease resistance and weed control ability decrease,
- cultivation can be performed in a worse quality and it demands more energy.

4. 6.4 The aim and necessity of deep tillage

The aim of deep tillage: to loosen the soil layers blocking the water conduction and root growth in the deeper layers of soil as a result of the development processes of the soil or due to other soil-related and agrotechnical reasons.

The soil has to be loosened if

- its water permeability is worse than average <10 mm/hours
- its volumetric weight is higher than 1.50 g/cm³
- its penetration resistance is higher than 3.5 MPa (at FC),
- soil: the water/air ratio is worse than 80/20,
- the soil profile is strongly swelling,
- there is a layer which blocks water permeability and root growth, (iron pan, lime barrier, cemented gravel, gley layer, etc.),
- it is necessary for erosion prevention purposes,
- if the operation of the subsurface drainage makes it necessary.

BIRKÁS (1994) refers to soil loosening as the first and most important method of ending the severe compaction of soil: “The regular, moderately deep and deep loosening and periodically changing use of soil looseners is not a luxury, but a very important method of improving and maintaining the favourable physical-biological condition of the soil.”
6. The necessity, method and tools of deep tillage

5. 6.5 Method of deep tillage

Deep tillage with rotation (with ploughing)

Deep tillage can be used where it does not ruin the following in connection with the regularly cultivated soil layer:

- the quality of humus;
- physical, water management and colloidal characteristics, i.e., its structure and cultivability;
- chemical characteristics, nutrient supply ability;
- no significant reduction of the humus content of the regularly cultivated layer.

Due to the fact that the humus content of soils usually decrease with increasing depth (Figure 3) and the unfavourable physical, but especially chemical characteristics, deep tillage is limited to a relatively small area. Deep tillage should only be used after the physical and chemical examination of the soil has been carried out. The tools of deep tillage are the various deep ploughs.

Deep cultivation without rotation

The tools of deep cultivation without rotation (deep loosening) are stiff chisel and active deep looseners. In the case of deep tillage, the optimum time for carrying out the procedure is determined by the mechanical capacity and the available time frame depending on the given crop cycle.

The favourable effect and duration of effect of deep cultivation without tillage can only be complete if the moisture content of the field is as low as possible, but at least 50-60% of the natural field capacity. If cultivation is carried out at the optimum moisture content level, the efficiency of deep loosening can be seen on the elevated soil surface due to the volume increase resulting from loosening. If there are only cracks instead of elevation after loosening, it refers to a low loosening impact. Therefore, based on the above statements, the procedure can only be performed if the moisture content of the soil layer to be loosened decreases to a lower level which is optimal from the aspect of carrying out deep loosening in a high quality. It follows from this that the time and volume of the usability of deep loosening are determined by the amount and distribution of precipitation, as well as the available mechanical capacity. Therefore, this type of cultivation only fits the tillage system with certain conditions.

Depth of deep cultivation

- it should adapt to the depth of the layers in need of loosening,
- in the case of soils where the whole profile needs loosening, the loosening depth provided by the machinery should be applied in order to perform this operation as deep as possible (Figure 40.),
- where loosening is not that deep, depth is also determined by the time- and energy-saving character.

The effect duration of deep cultivation in the case of the deep loosening of non-irrigated soils is 3-4 years and 2-3 years on irrigated soils.

In order to enforce the yield increasing effect of deep loosening, the production crops which react positively to deep loosening should be increased as much as possible in the years after loosening. These crops include sugar beet, potato, maize, alfalfa, soybean.

6.6. ábra - Figure 40. The maximum depth of tillage and deep loosening on calcareous chernozem soil
6. The necessity, method and tools of deep tillage
7. fejezet - 7. Land use methods (crop rotation, crop cycle, monoculture)

1. 7.1 Crop rotation

1.1. 7.1.1 Classic crop rotation

The classic crop rotation crop production system was developed from the tripartial rotation system in the 17th-18th centuries. It is a planned system of crop production in which the composition and ratio of crops is constant for a longer period, crops are produced in accordance with an order previously developed in time and space in their original field in a determined period of time. There are four basic elements of the system. Neither of these can be missing, as they are the prerequisite of classic crop rotation.

Crop composition:

- the crop species produced in the given crop rotation.
- the collective of crops produced on the given farm or on a certain part of the farm.
- there could be significant differences in the number of the produced crops, in extreme cases, this number can be reduced to 3, decades ago, the production of 10-20 crops was frequent

Proportion of crops:

- it shows what percentage each crop has in the crop rotation.

Crop order:

- determines how each crop follows the other.

Rotation:

- the duration (years) under which the given crop is produced in the same field at the end of the rotation.
- the duration during which all crops of the crop rotation was produced in all fields.

Example:

<table>
<thead>
<tr>
<th>Order</th>
<th>Composition</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>Winter wheat</td>
<td>25 %</td>
</tr>
<tr>
<td>Year 2</td>
<td>Winter coleseed</td>
<td>25 %</td>
</tr>
<tr>
<td>Year 3</td>
<td>Winter barley</td>
<td>25 %</td>
</tr>
<tr>
<td>Year 4</td>
<td>Maize</td>
<td>25%</td>
</tr>
</tbody>
</table>

4-year rotation

In the previous example, the given crop composition is obtained each year only if production is carried out on four fields
Land use methods (crop rotation, crop cycle, monoculture)

<table>
<thead>
<tr>
<th>Year</th>
<th>Classic crop rotation</th>
<th>Frame crop rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Winter wheat</td>
<td>Winter cereals (Winter wheat, barley)</td>
</tr>
<tr>
<td>2</td>
<td>Winter coleseed</td>
<td>Cruciferous crops (mustard, radish)</td>
</tr>
<tr>
<td>3</td>
<td>Winter barley</td>
<td>Winter cereals</td>
</tr>
<tr>
<td>4</td>
<td>Maize</td>
<td>Root crops</td>
</tr>
</tbody>
</table>

The other elements of frame crop rotation (crop order, crop ratio, rotation) are the same as those of the classic crop rotation.

The crop rotation could be: field, forage and special crop rotation.

Crop cycle

The crop cycle is a planned system in which crops belonging to similar or different agrotechnical groups in alternating order in a given area. It is a land use system which was developed in parallel with crop rotation. In practice, it is not possible to use a crop rotation which contains 5-10 or more crops. The basic guidelines of putting together the crop order are still present in this system.

Crop order variations

Example:

Crop cycle with changes in one, two or three years
7. Land use methods (crop rotation, crop cycle, monoculture)

<table>
<thead>
<tr>
<th>Year</th>
<th>Yearly change</th>
<th>Change every 2 years</th>
<th>Change every 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>Maize</td>
<td>Maize</td>
<td>Maize</td>
</tr>
<tr>
<td>Year 2</td>
<td>Winter wheat</td>
<td>Maize</td>
<td>Maize</td>
</tr>
<tr>
<td>Year 3</td>
<td>Winter coleseed</td>
<td>Winter wheat</td>
<td>Maize</td>
</tr>
<tr>
<td>Year 4</td>
<td>Winter wheat</td>
<td>Winter wheat</td>
<td>Winter wheat</td>
</tr>
<tr>
<td>Year 5</td>
<td>Maize</td>
<td>Winter coleseed</td>
<td>Winter wheat</td>
</tr>
<tr>
<td>Year 6</td>
<td>Winter wheat</td>
<td>Winter wheat</td>
<td>Winter wheat</td>
</tr>
</tbody>
</table>

In Hungary, change every two years and the dominance of maize and winter wheat are frequent. The reason for this is that the production sizes of wheat and maize are nearly identical (wheat: 1991-2001 1.05 mill. ha; maize: 1.15 mill. ha)

Biculture: change every two years, triculture: change every three years.

Rational crop cycle could result in yield surplus, reduced energy expenditure and improved culture conditions of the soil, while the environmental load can decrease significantly.

1.4. 7. 1. 4. Monoculture

Monoculture is production without crop cycle. Temporal monoculture means that a certain crop is produced in the same area for years. Spatial monoculture means the concentration of species or species combinations in a given area.

The production of perennial crops (e.g. alfalfa for 4 years) is not considered to be monoculture. Under Hungarian circumstances, the following crops can be produced in monoculture: maize, rice, rye. Main crops produced in monoculture abroad: maize, rice, rye, cotton, coffee. In the monoculture system, “interrupting” plants are also produced occasionally (melilot).

The advantages of monoculture production:

- The soil can be adjusted to the characteristics of the produced crop.
- The climate could be the most beneficial for the produced crop.
- The producer becomes a professional of the given crop’s production.
- The producer does not have to be dealing with the farming all year.
- The costs of mechanisation could be lower.
- The profitability of production could be better.

Advantages of crop cycle:

- More continuous crop coverage, the damage of erosion can be reduced.
- The physical state of the soil can be more favourable.
- Deeply rooted legumes can be produced occasionally.
- Weed coverage can be reduced.
- The damage done by pathogens and pests can be reduced.
- The work need can be extended and the income of crop production arises in different periods.

2. 7. 2. Aspects influencing the crop composition

2.1. 7. 2. 1. Natural factors

The most important climatic factors are the length of the vegetation period, temperature factors and precipitation factors. The growing season of crops cannot be longer than the vegetation period, as it is not possible to harvest a ripened yield. The mean temperature of the vegetation period is important from the aspect of the crop’s temperature need. In addition to precipitation sum, the temporal distribution of rainfall is also important.

The soil characteristics limit the range of crops that can be produced. On soils with high productivity and favourable physical conditions, the range of crops that can be grown in wide.

The configurations of the terrain have significant importance during the determination of crop composition in mountainous and hilly areas.

2.2. 7. 2. 2. Biological factors

During the planning of crop composition, it is important to consider the amount of water needed to achieve the yield of the given crop on an area unit. Crops which have shorter growing seasons need less water. The nutrient need has to be calculated in accordance with water need and the nutrient stock of the soil has to be used as a basis.

Crop varieties have different pathogens and pests which need to be taken into consideration. Different crops have different impacts on weed coverage.

The amount of root and crop residues changes with the crop composition. In each production system, organic residues have to be transferred back into the soil so that they can be utilised or they should protect the soil if they are left on the surface.

2.3. 7. 2. 3. Economic aspects

It is the prerequirement of profitable farming to know customers’ demands and needs and to adjust them to the opportunities of the given economy (living labour, technical preparedness, expertise). In some cases, the natural and biological factors determine whether certain crops can be grown or not. At the same time, crops which have favourable previous crop effect could be excluded from the sowing structure due to aspects of economicalness.

3. 7. 3. Aspects of developing the crop order

3.1. 7. 3. 1. Previous crop value: the measurable impact of the previous crop on the yield and production technology procedures of the catch crops.

Aspects determining the previous crop value:
- impact depending on the production site,
- the impact of the previous crop on the soil,
- yield of the previous crop,
- infestation of the previous crop with pathogens and pests,
7. Land use methods (crop rotation, crop cycle, monoculture)

- weed coverage of the previous crop,
- technology used during the production of the previous crop,
- the quantity and crushability of the previous crop residues.

On highly productive soils, the unfavourable impact of the previous crop could be less emphasised as opposed to weak soils. The impact of previous crops on the soil is versatile and it can be expressed in the impacts on nutrients, water stock, structure and the organic matter content.

Due to their ability to bind atmospheric nitrogen, papilionaceae and legumes are considered to be more favourable previous crops than maize or sugar beetsugar beet which have high nutrient need. Due to the compaction damages caused during the harvesting of sugar beetsugar beet, the soil after harvesting sugar beetsugar beet will be in an unfavourable condition. Catch crops have to be selected by making sure that they are not too sensitive to adverse circumstances. For this reason, mostly winter barley is sown as a catch crop of sugar beetsugar beet.

The higher the yield of the previous crop is, the more nutrients it extracts from the soil. Legumes and perennial papilionaceae are exceptions, as their high yields leave more root residues and nitrogen in the soil which is favourable for catch crops and it decreased the costs of fertilisation. The infestation of previous crops with pathogens, pests and weeds significantly reduces their value, independently of what the catch crop will be. The longer time passes from the harvesting of the previous crop to the sowing of the catch crop, the higher value the previous crop will be. The value of the previous crop is significantly determined by the technological procedures used during its production. Based on the amount of the crop residues and crushability of the previous crop, as well as its infestation with pathogens, it can be decided whether tillage is necessary or the crop residues can stay on the surface.

### 3.2. 7. 3. 2. Previous crop need

Previous crop need: the need of the plant to be produced from the previous crop. The collective of biological and agronomic requirements helping the production of the catch crop. It is important to know the circumstances in order to form the favourable crop order. The basic principles of previous crop value and previous crop need have to be used in every farm that produces several crop species. Farming without any system which neglects the fundamental needs and post-effect of crops will lead to the reduction of yield and soil degradation that eventually results in the decrease of income.

The favourable previous crops of winter wheat are legumes which are harvested in early summer, winter coleseed and other cruciferous crops, as well as crops which are harvested until early September (poppy, tobacco, potato). Silo maize, hemp, early harvested grain maize, potato harvested until the end of September, sugar beetsugar beet, field vegetables and sunflower are medium previous crops. Winter wheat cannot be successfully produced in monoculture and it is rather sensitive to previous crops in a crop rotation. At least four years have to pass before winter wheat can be sown again. Winter barley can be the catch crop of winter wheat only if there was previously winter wheat on the plot only for one year and not more. Early potato, mustard, legumes (e.g. pea), silo maize and several crops harvested until early September are good previous crops of rye. Medium previous crops are maize harvested until late September, sunflower, lupine and tobacco. Rye can also be produced without any change, as it is rather resistant to monoculture. Also, it has a favourable impact on the physical and biological conditions of the soil if it is grown as green manure crop before a spring-sown crop or as intermediate crop for soil protection purposes. In this case, the crop residues have to be incorporated into the crop to a shallow depth until mid-April the latest.

Sugar beet, early maize and silo maize are good previous crops of spring barley. Medium previous crops are sunflower, hemp and fibre flax. It is not recommended to sow spring barley after cereals and legumes.

Possible previous crops of oat are cereals and root crops. Oat production has to be avoided after sugar beetsugar beet, potato, tobacco and vegetables. Repeated oat growing has to be avoided for 3-4 years after harvesting.

The most adequate previous crops of maize are cereals. Maize is less sensitive to monoculture than winter wheat.

Sugar beetsugar beet is sensitive to soil conditions. There is enough time for the adequate quality of seedbed preparation after autumn and spring cereals. Oil flax, fibre flax and silo maize are medium previous crops.
Growing sugar beets without any change is not recommended, since the nematode worms which proliferated under the sugar beets can still do damage after three quarters of a year; therefore, sugar beets can be sown again on the same area after 5 years the earliest.

The best previous crops of potato are ear cereals, white mustard and oilseed radish. Medium previous crops are flax, rape, pea and annual rough fodder crops. Potato can be sown again after four years, except in the case of sandy soils, where potato can be sown again in three years. After pea, at least 4-5 years have to pass before it can be sown again on the same field. In Hungary, it is grown between two ear cereals, but sometimes it has root crops as previous crops.

Sunflower can be successfully produced after basically any previous crop except for itself and perennial legumes if there are adequate agrotechnics. The monotony of the wheat – maize crop cycle can be broken by inserting sunflower into the crop order. It can return to the same area after 5-6 years.

As regards rape, given the typical sowing structure in Hungary, the crop order of cereals – rape – cereals became accepted. When planning the area of rape, attention must be paid not to sow it in a field where rape, mustard or radishes were produced some when during the last 4-5 years.

### 3.3. 7. 3. 3. Returning time

Returning time: the duration of time expressed in years after which the crop which cannot directly follow itself in the rotation is produced in the same field again. The returning time has biological causes, in most cases, it has crop production-related causes (pathogens, pests, weeds). The returning time is determined by how long one has to expect the increased presence of the species- or the variety-specific pathogens and pests. (cereal nematodes, cyst nematodes, fusariosis, sunflower broomrape).

Duration (after which it can be grown after itself):

- 3 years: oat, potato, tobacco, hemp, lentin, crimson clover, etc.
- 4 years: winter barley, sugar beet, winter coleseed, oil and fibre flax, poppy, pea, soy, bean, red clover, etc.
- 5-6 years: sunflower.

### 3.4. 7. 3. 4. Concentrability

Concentrability: total area proportion of crops which cannot be sown after themselves compared to the total suitable area, depending on returnability.

For example, one would like to produce sugar beets on a 200 ha plot. The returning time of sugar beet is 4 years; therefore, it cannot be grown on the whole area. Calculation of concentrability: total suitable area/returning time. Therefore, one quarter of the area (50 hectares) can be used for sugar beet production each year if the goal is to produce sugar beets constantly.

### 4. 7. 4. Natural science bases of crop cycle

The theories explaining the favourable impact of crop cycle are mostly of natural science and economics-related. Several different views were developed regarding the evaluation of the importance of crop cycles, independently of production site and economic circumstances. From the 1800s, researchers all over the world have been doing experiments and trying to verify their theories in different ways.

#### 4.1. 7. 4. 1. Long-term experiments

There are numerous long-term experiments worldwide aiming at the comparison of crop production systems. On the one hand, this goal of these experiments is to examine the fertiliser reaction, weed proliferation and fertiliser tolerance of crops in crop rotation and monoculture, while the temporal changes of yields and the various reasons for yield reduction are also researched on the other. Based on the first 80 years (1879-1958) of the "eternal" rye production experiment, Konnecke Halleben determined different phases in the yield fluctuation of rye. The yield of rye growing without any change reduced to a lesser extent as a result of fertilisation, despite the fact that the amount of nitrogen withdrawal was nearly the same on areas where farmyard manure and...
artificial fertiliser were applied. In Rothamsted, in the winter wheat and winter barley monoculture long-term experiment, it was established that fertilisation counterbalanced the lack of crop rotation more effectively in the case of spring barley than winter wheat. In Illinois, Ohio and Iowa (USA), the monoculture production of maize is still a widespread practice. In order to effectively counterbalance the yield-reducing effect of one-sided nutrient use, as well as to provide adequate protection against weed proliferation, pathogens and pests, effective chemicals and resistant hybrids (GMO) were developed. Based on the long-term experiment results obtained in Hungary, it can be established that the extent of yield reduction resulting from monoculture is significantly affected by production site factors, especially climate and soil conditions, in addition to the general crop production standards, fertilisation, tillage, crop protection and irrigation. The differences change in accordance with the given crop species and even varieties.

4.2. 7. 4. 2. Humus theory

Thaer identified humus increasing and humus consuming field crops in the early 19th century. Through changing the proportion of these crop types within the crop rotation, the organic matter stock of the soil can be maintained or increased. The basis of differentiation is the amount of root mass and the organic crop residues that are left on the surface after harvesting. Accordingly, perennial legumes and grasses were categorised into the humus increasing group, while cereals and root crops belong to the humus consuming group. During the development of a crop rotation, the aim is to maintain or increase the organic matter stock of the soil. The correlation between the amount of the organic matter left in the soil and the harvested yield is always positive. The production technological procedures which increase yield also increase the quantity of the organic matter remaining in the soil and on the surface.

Experiments show that this grouping of crops is not justified. Cultivation affects organic matter development and breakdown through the disturbance of soil and CO2 emission, while fertilisation acts through the biomass of crops. Higher yields result in more organic residues which can then be transferred back into the soil. The agrotechnological systems in which the nutrients withdrawn with yields can be replenished in a permanently sustainable way, crop residues are transferred back into the soil and organic matter-preserving cultivation is used are becoming more preferred.

4.3. 7. 4. 3. Nutrient theory

According to Liebig’s minimum theory, yield is controlled by the scarcest resource. Liebig replenished the nutrients which he found in the ashes of crops, but he underestimated the significance of nitrogen supply. Liebig’s mineral substance theory was completed with Boussingault’s nitrogen theory to become a nutrient theory that is based on the different nutrient uptake of plants. Different plants need nutrients in different amounts and proportions; also, the nutrients taken up by crops are transferred back into the soil in different amounts.

4.4. 7. 4. 4. Nitrogen theory

Boussingault, a French chemist proved the nitrogen binding ability of legumes with experiments. The alternating production of legumes and non-legumes is an important factor in maintaining soil fertility. None of the produced plants are able to enrich the soil in mineral nutrients. Even the nutrient uptake ability of crops is not the same. In the case of regular fertiliser use, the questions of nutrient theory become less important, but the obtained experience can also be used in the environmental friendly production systems.

4.5. 7. 4. 5. Structure theory

Williams classified crops into structure improving and structure degrading groups and he also established that the production of perennial grasses improves soil structure, but overestimated the role of permanent structure. The good structural condition of the soil can be preserved and improved without grass in the crop rotation and by producing other perennial and annual crops as well as by using rational production and fertilisation systems. The effect of crops on soil structure can be significantly modified by the processes used during production and harvesting. Compaction can totally deteriorate the otherwise favourable effect of crops. For this reason, the reduction of compaction and the number of operations on the field should be reduced. Structure theory in itself is not enough to justify the advantages of crop rotation and crop cycle systems. The production of certain crops can have a negative impact on the soil structure, especially if the agrotechnical operations also have a preserving effect.
4.6. 7. 4. 6. Water use theory

It is based on the difference between the water need and water uptake of crops.

Crops can be classified in terms of the amount of water they use (low, medium, high). This classification represents the utilisable water stock that crops leave in a given layer of the soil after they are harvested. Crops use up different amounts of water until harvesting; therefore, the amount left is also different. For this reason, classification is in connection with the time of harvesting.

Low: pea, poppy, spring feed mixes.

Medium: winter and spring cereals.

High: maize, sugar beet, sunflower, sorghum species.

The water use theory has more significance in dryer climatic zones. The different water use of crops should be considered mainly in dry areas where the amount of precipitation is low and in the case of late summer (rape, alfalfa) and autumn-sown crops. After a dry growing season, the impact of a high water consumption previous crop will be even more adverse than usual. The yield reduction effect of drought during the growing season is especially high in the case of producing maize in monoculture if there was little precipitation also during the previous winter period.

4.7. 7. 4. 7. Root rotation theory

This theory is based on the difference in the quantity, quality and the vertical location of the produced crops’ root mass in the soil. This difference can be exploited by the positive crumb formation effect on the soil structure, while some dead root systems can also have an especially beneficial impact on the water cycle of the soil.

One of the indexes of root quality is the C/N ratio (perennial and annual legumes 1/18-20; cereals 1/40-45; sorghum species, sunflower 1/50-70). Tighter C/N ratio means easier decomposition; therefore, more favourable N balance.

The largest amount of root is located in the upper 20 cm layer of the soil.

Crops can be classified into deep, medium and shallow rooted crops.

Deep: alfalfa, red clover, lupine. They dry out the soil more and deeper than medium and shallow rooted crops.

Medium: winter and spring cereals.

Shallow: flax, pea, bean.

The largest amount of root mass (5-10 t/ha) is produced by perennial legumes, grasses and sorghum species.

Crop producing medium amount of root mass (2-6 t/ha): maize, sunflower, autumn cereals and winter coleseed.

Lowest root mass amount (1-2.5 t/ha): spring barley, pea, vetch species.

The crop cycle production of shallow or deeply rooted crops which produce smaller or larger root mass has significance primarily under dry circumstances.

4.8. 7. 4. 8. Weed proliferation

In the case of production without crop cycle, certain weed species could proliferate.

Crop cycle is the cheapest and one of the most efficient tool of weed control.

Not all culture crops provide favourable ecological conditions for the germination of weed seeds in the soils and the development of the weeds. Crops of different sowing dates and growing seasons are associated with different weed flora. In the case of production without any crop cycle, certain weeds can proliferate to an extent
(e.g. cockspur, Johnson grass and bermuda grass in maize) that their suppression can only be achieved with special methods.

4.9. 7.4. 9. Soil sickness

Soil sickness refers to the negative phenomena in the development and yield of crop species produced in the same field for years. Soil sickness can appear in various phases of crop development.

According to Könnecke, possible reasons of soil sickness include nutrient shortage, plant pathological causes, organism theory and toxin theory.

Nutrient shortage can be stopped with proper nutrient replenishment; therefore, soil sickness cannot be explained with nutrient shortage.

Producing the same crop without and switch contributes to the spreading of and damage done by plant pathogens. Due to root rot, stem base diseases and nematodes, the production of several crops can only be performed after several years have passed. Nowadays, crop protection-related causes also make crop cycle necessary.

The basis of organism theory is that crops block or stimulate the activity and proliferation of microorganisms in the soil with their root secretions within the range of their root system. Microbae influence soil condition and the development of crops. In monoculture production, the biological balance is unsettled and metabolism products secreted by microorganisms will be accumulated, thereby deteriorating their living space. This condition can be stopped with crop switches. Soil sickness cannot be explained with the organism theory only.

According to the toxin theory, an organism’s own secretion and decomposition product is toxic to itself. The presence of toxic substances in plant and soil extracts is proven. Soil temperature, its water and air management, acidity and microflora improve the breakdown of toxic substances. Intoxication can be prevented with agrotechnical tools; therefore, the toxin theory does not have any real significance.

Allelopathy refers to the blocking effects of higher level plants between each other, as well as between them and microorganisms. The blocking effects acting on the vital functions of various organisms is constantly researched. As a result, several compounds were isolated whose production and use had good results in crop protection and weed control. The frequent yield reduction in crop production without any switch could result from several simultaneous factors whose mode of action is still unknown.
8. fejezet - 8. Tillage systems used in Hungary

1. 8.1 Conventional tillage

The whole soil surface is cultivated (clean tillage). The area of field residue does not exceed 15% after sowing. The primary tillage tool is the plough (Figure 41). The finishing of the primary tillage is performed with simple tools (smoother, roller, disc), while seedbed preparation is usually done with a cultivator. The use of machinery connections is infrequent. The procedures improving cultivation quality are often omitted (e.g. stubble stripping, treatment, surface finishing). The number of operations in this tillage system is 5-9/10.

8.1. ábra - Figure 41. Conventional tillage with mouldboard plough

2. 8.2 Improved conventional tillage

The whole surface is cultivated. Use of bed plough or reversible plough for primary tillage (Figure 42). Using modern tool combinations for surface finishing and seedbed preparation. Performing soil loosening occasionally. The number of operations in this tillage system is 4-6.

8.2. ábra - Figure 42. Conventional tillage with reversible plough
3. 8.3 Reduced tillage systems

3.1. 8.3.1. System built on heavy cultivator use

(Figure 43). It can be used in the case of summer, late summer and autumn sown crops and after early harvested green crops.

System steps:

- Stubble stripping with cultivator, shallow, with surface finishing.
- Treatment of stripped stubble with cultivator, slightly deeper than the stripping, surface finishing.
- Primary tillage with cultivator, reaching the maximum depth (steps 2 and 3 can be done in one operation).
- Seedbed preparation in one operation.
- Sowing and post-sowing surface finishing in one operation.

Advantages: less number of operations, time, energy and cost saving, preserving the soil structure, reducing moisture loss.

Barriers: strong weed infestation, large amount of dried stubble residue, too wet soil, compacted soil condition in the deep, need to learn.

Note: it is used the least often currently.

8.3. ábra - Figure 43. Tillage with heavy cultivator
3.2. 8.3.2 System based on Ripper

The system based on moderately deep loosening can be used on stripped stubble field in the case of any plant in terms of sowing period, especially if the soil is extremely compacted at the 30-40 cm depth. The aim of using moderately deep loosening is to improve the condition of deeper soil layers and to ease the environmental damage (compaction) arising from cultivation mistakes (Figure 44).

System steps:

- Stem crushing if necessary.
- Stubble stripping, surface finishing.
- Treatment of stripped stubble, slightly deeper than the stubble tripping, surface finishing.
- Primary tillage with ripper + total surface tillage with disc or plough
- Surface finishing and seedbed preparation in one operation or separately.
- Sowing and post-sowing surface finishing in one operation.

Advantages: improvement and maintenance of the soil conditions.

Barriers: wet soil condition, need to learn.

Note: it is used the least often currently.

8.4. ábra - Figure 44. Ripper tillage equipment
3.3. 8.3.3 Disc tillage system

It can be used in the case of summer, late summer and autumn sown crops and after early harvested green crops.

System steps:

• Stubble stripping with disc, surface finishing.

• Treatment of stripped stubble, slightly deeper than the stripping, surface finishing.

• Primary tillage with disc, reaching the maximum depth of 18-20 cm (steps 2 and 3 can be done in one operation) (Figure 45).

• Surface finishing and seedbed preparation in one operation or separately.

• Sowing and post-sowing surface finishing in one operation.

Advantages: reduced number of operations, time, energy and cost saving.

Barriers: wet soil condition, compactedness of deeper soil layers (below 20 cm), previously dustified soil structure.

Note: currently, it is used more often than desirable.

8.5. ábra - Figure 45. Disc harrow

3.4. 8.3.4 Tillage and seeding cultivator
Soil disturbance is performed until the depth of sowing on the total soil surface. Sowing in one operation with a seeding cultivator. The seeding row is not straight, but it does not deteriorate the quality of harvesting with a combine-harvester even in the case of root crops. This method is recommended to be used in areas prone to drought, on large plots, in the case of producing commercial or energy crops and in years between deeper cultivations. The limit of this method is the presence of the compacted closing layer close to the surface which can be decreased with periodical loosening. It can be used in the case of crops sown anytime, if the soil is not compacted under 10 cm.

System steps:

Autumn cereals:

• Stubble stripping and treatment after early harvested green crops.
• Stem crushing after late harvested green crops
• Primary+secondary tillage in one operation.
• Sowing with seeding cultivator and surface finishing in one operation.

Spring cereals or crops:

• Stubble stripping and treatment after early harvested green crops.
• Stem crushing after late harvested green crops.
• Primary tillage + partial finishing in one operation in the autumn (this step can even be omitted).
• Sowing with deeding cultivator and surface finishing in one operation.

Advantages: reduced number of operations, time, energy and cost saving, reducing moisture loss, soil structure preservation.

Barriers: compactedness of the soil layer below 10 cm, high learning need.

Note: currently, its use is not widespread.

8.6. ábra - Figure 46. Seeding cultivator

3.5. 8.3.5 Strip tillage

Strip-tillage is a form of conservation tillage systems (Figure 47). It combines the benefits of conventional clean tillage with the soil-protecting advantages of no-tillage systems. The soil is tilled in 25-30 cm wide, the crop residue removed from the tillage zone. The tillage zone is typically 25 to 30 cm wide and 25 to 30 cm deep. The soil disturbance affects one third of the area. The soil surface between these strips is left undisturbed. The
residue from the previous crop remain on the soil surface. The residue-covered area reaches 60-80%. Keeping residue on the surface helps prevent soil from wind and water erosion and reduce water loss from the soil.

Strip-tillage is most common with crops on 76 cm row spacing. It can be adapted to row spacing down to 50 cm. Maize, sunflower, soybean have all been successfully strip-tilled.

The accurate implementation of strip tillage cannot be precisely applied without the aid of Auto Trac Guidance System. Real time kinematic global positioning system is recommended for positioning accuracy for strip tillage.

System steps:

- Stubble stripping, surface finishing.
- Primary tillage + secondary tillage + fertilisation + seedbed preparation in one operation.
- Sowing and fertilisation into the loosened strips in the spring.

Advantages: Reduces soil erosion because most of the soil remains covered with crop residue throughout the year. Releases less carbon into the atmosphere and maintains higher levels of soil organic matter. Conserves soil moisture because most of the soil surface area is covered with crop residue. Reduces expenses, including fuel and labour, by eliminating some primary and secondary tillage.

Barriers: Strip tillage will require more management, skill, and planning than conventional tillage. Conventional tillage stirs the soil more thoroughly, incorporating more residue than strip tillage and making planting easier. Conventional tillage does not require as precise driving when planting. Conventional tillage may allow more flexibility in timing for weed control. Cooler soil temperature in the spring is one of the problems with leaving residue and not tilling. The limits of this method are the presence of a compacted closing layer close to the surface (it can be reduced with strip soil loosening!) and the high level of perennial weed infestation (it can be reduced with regular mechanical weed control 3-4 years before introducing this method).

Note: it is used in an increasing area.

8.7. ábra - Figure 47. Strip-tillage
3.6. 8.3.6 Combined soil tillage and sowing

It can be used in the case of crops sown in different times of the year, but usually autumn or spring sown cereals.

System steps:

Autumn cereals (after early harvested green crops):

• Stubble stripping, shallow, surface finishing.
• Treatment of stripped stubble, slightly deeper than the stripping, surface finishing.
• Primary tillage + secondary tillage + seedbed preparation + sowing + post sowing surface finishing in one operation or Primary tillage separately and everything else in one operation.

Spring cereals:

• Stem crushing (autumn).
• Primary tillage + secondary tillage + seedbed preparation + sowing + post sowing surface finishing in one operation (Figure 48). Or: Separate primary tillage in the autumn, every other step in one operation in the spring.

Advantages: reduced number of operations, time, energy and cost saving, reducing moisture loss, soil structure preservation.

Barriers: adaptation to the moisture content of the soil, usage of loosening combination in the case of the compactedness of layers below 20 cm. It is important to properly learn the technology.

Note: narrow range of use.

8.8. ábra - Figure 48. Combined soil tillage and sowing
3.7. 8.3.7 No-till

No-till farming is defined as farming where the soil is left relatively undisturbed from harvest to planting. During the planting operation, a narrow seedbed is prepared or holes are drilled in which seeds are planted (Figure 49). Soil disturbance is done only at the time of sowing, in the seeding row on not more than 10% of the surface. It can be used in the case of crops that can tolerate production without tillage. The agronomical limits of the method are the presence of the compacted closing layer close to the surface and the strong weed infestation.

System steps:

- Stem crushing if necessary.
- Chemical weed control in the pre-sowing period.
- Direct seeding, fertilisation, weed control spraying in one operation.


Barriers: No plant incorporation into the soil. Increased dependence on herbicides. Slow soil warming on poorly drained soils.

Note: narrow range of use.

8.9. ábra - Figure 49. No-till planter

1. 9. 1. Fundamental concepts of nutrient management

Soil conservation is a long-term, rational activity which, in addition to crop demands, considers the impact of the applied fertilisers on the soil and the environment.

One of the prerequirements of agricultural production is the proper supply of nutrients. In addition to the quantity of nutrients in the soil, their availability and adequate proportion are also important and it can be provided mainly with artificial nutrient replenishment, i.e. fertilisation.

By fertilisation, i.e. yearly nutrient replenishment which helps crop development, the amount of nutrients necessary for the next yield is provided and the actual level of nutrient supply is improved. The aim of fertiliser use is the economical increase of yield, the realisation of quality needed by consumers and the reduction of quality and quantity fluctuations caused by different crop years.

Fertilisers are nutrients applied onto the soil surface or directly the crops themselves which increase the amount of nutrient stock available to the produced crop. It is also important to improve the availability of nutrients in the soil which cannot be directly utilised by crops, which can be provided by proper organic matter management, water supply, liming and other agrotechnical operations. In a wider sense of the word, fertiliser types are the materials which improve the availability of the nutrients directly not utilisable for crops and improve soil productivity. The amount of nutrients taken up through the roots depends on the nutrient uptake ability of crops as well. This ability is determined by the size of the active root surface of crops, the ion exchange capacity of roots, as well as the amount of root fluids secreted in order to extract nutrients.

Water and nutrients are needed for the growth and development of crops, as well as the building of their structure. Nutrients play a many-sided role in crop metabolism, growth and healthy development. Nutrients are indispensable and cannot be substituted with each other.

Nutrients are chemical elements which are needed for the proper development of crops and cannot be substituted by any other element.

Indispensable elements: carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, manganese, copper, zinc, molibdenum, boron, sodium, chlorine, silicon.

The necessary amounts of nutrients are rather different depending on the given crop; therefore, they are classified as macro- and micronutrients.

<table>
<thead>
<tr>
<th>Macronutrients</th>
<th>Nitrogen, Potassium, Calcium, Phosphorus, Magnesium, Sulphur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micronutrients</td>
<td>Iron, Manganese, Copper, Zinc, Molibdenum, Boron, Chlorine</td>
</tr>
</tbody>
</table>

Nutrient uptake is done in a way that nutrients get into the crops from the soil solution mainly in ionised and partially in molecular form via the root system through the rootlets.

2. 9. 2. Factors influencing the effectiveness of fertilisers

2.1. 9. 2. 1. Crops to be produced (species, variety, hybrid)

It is the fundamental condition of the successfulness of fertilisation to produce crop varieties which utilise fertilisers the best way under given circumstances and to use a production technology which increases the yield
increasing impact of fertilisation (tillage, sowing, crop care, etc.). Fertilisation, as one of the main factors of crop production has a significant impact on yield. The effect of the purified variety and fertilisation represent around 50% in terms of yield increase. The high productivity of reliable varieties with high yield stability is the result of their better nutrient uptake ability. The varieties used in common production for a longer period can utilise the available nutrients of the soil even under extreme circumstances.

2.2. 9. 2. 2. The amount of applied fertilisers

In addition the adverse impact of insufficient nutrient supply on yield quality and quantity, it can also reduce crops’ resistance to pathogens and pests. The increase of weed coverage causes further increase of expenses. Pests can causes more severe damages in crop stands which develop weakly due to scarce nutrient supply.

2.3. 9. 2. 3. Method of application

The method and time of applying fertilisers could determine fertilisation efficiency crucially. The incorporation of farmyard manure can be done with the late summer – autumn primary tillage. Phosphorus and potassium is utilised to a greater extent if they are applied before the autumn primary tillage. Steady mixing of these nutrients into root zone increase the level of utilisation. The autumn application of nitrogen is justified in the case of autumn-sown cereals or the incorporation of a large amount of organic matter into the soil. Nitrogen fertilisation can be performed in the spring in one operation with sowing, or as side-dressing or in separated doses, depending on the crop’s need and the expected impact. The missing amount of nutrients can also be replenished with foliage fertilisation. The micronutrient to be replenished has to be determined with plant analysis and only the missing elements can be supplied with spraying.

2.4. 9. 2. 4. The standard of the applied agrotechnics

The water management of soils, the availability of nutrients and the utilisation level of fertilisers becomes more favourable with proper tillage. In properly aerated soils which have good structure, the activity of microbae improving mineralisation is more powerful and the risk of denitrification is lower.

2.5. 9. 2. 5. Weather factors

Nutrient management shows a close ulink with the water supply of the soil. Material flow and diffusion processes can work only in a wet medium. Drought circumstances deteriorate the utilisation of fertilisers. Nevertheless, too rainy weather could also reduce efficiency due to the runoff losses and the denitrification resulting from the airless soil conditions.

2.6. 9. 2. 6. Soil acidity

Soil acidity affects the availability of each nutrient and helps certain harmful ions get into the soil solution. Also, soil acidity has a crucial effect on the vital functions of microorganisms.

It is important to know soil acidity as it determines the necessity of soil improvement on the one hand and it affects the selection of crop to be produced, as well as the method of fertilisation and fertilisers themselves on the other.

From the aspect of nutrient uptake of crops, slightly acidic, close to neutral soils are ideal. In acidic soils, ferro- and aluminium phosphates are formed, while the alkaline medium is favourable for the formation of calcium phosphates. Therefore, the uptake of phosphorus can be blocked by soil acidity.

A strongly acidic medium has an adverse impact on crop development which is the result of the toxic amount of micronutrients an the calcium shortage. Also, the stability of soil colloids decrease, the water and air management of the soil deteriorate. The amount of exchanged metal cations increases in the soil solution; therefore, they are easily leached. The acidification of soils could be increased by a high volume of fertiliser use, especially ammonium chlorides and urea.

2.7. 9. 2. 7. Nutrient content of the soil
The nutrient content of the soil covers the total amount of nutrients in the soil, while the proportion that is present in an available form is referred to as nutrient potential. It is possible to conclude whether crops can take up nutrients in accordance with their needs on the basis of the nutrient supply ability of the soil. The amount of nutrients used in the production of the expected yield and the associated secondary yield is the nutrient need of the crop. Fertiliser need refers to the amount of active ingredients which have to be replenished in order to achieve the expected yield. The level of nutrient supply, i.e. the concentration of the available nutrients can be determined if one also considers other soil characteristics and the nutrient need of crops.

### 2.8. 9. 2. 8. Adsorption capacity of the soil

The ion binding ability of soil colloids is called adsorption, which is how plant nutrients can be stored in an easily available form in the soil surrounding the roots. There is a dynamic balance between the soil solution and the bound ions. Heavy soils rich in colloids have more expressed nutrient binding ability than loose soils that have low colloid content. For this reason, high fertiliser doses cannot be applied on heavy soils. In extremely heavy soils, the extent of adsorption can be so strong that it blocks nutrient uptake, resulting in a degraded effect of fertilisation. Accordingly, the development of mechanical, chemical and biological bonds of the soil’s nutrient binding ability should not be neglected either.

### 2.9. 9. 2. 9. Biodynamics of the soil

The microorganisms getting into the soil become available for crops again due to microorganisms. The speed of the mineralisation of the organically bound nitrogen depends on the carbon/nitrogen ratio of the organic matter. The breakdown of residues with a narrow (15/25) C/N ratio is faster than in the case of a wider range (>30) of C/N ratio.

The order of the breakdown process: aminisation, ammonisation, nitrification. The bacteria start an oxygen production process in the compacted, airless, and overly wet soil. During this process, they reduce nitrite from nitrate, then ammonia from nitrite. As a final result of denitrification, nitrogen gas is produced. In cases like this, even 30% of the applied fertiliser can be lost. The incorporation of crop residues of wide C/N ratio leads to the proliferation of cellulose-degrading bacteria. Microorganisms need nitrogen for their vital processes. The effect during which nitrogen is withdrawn for such purposes is called pentosan effect. This unfavourable impact can be prevented with the simultaneous application of a N fertiliser dose, followed by its incorporation into the soil.

The extraction of phosphorus bound in organic matter is done by soil bacteria, and the organic and inorganic acids have increasingly important roles during soil acidification.

### 3. 9. 3. Correlation between fertilisation and agrotechnical factors

The role of the different production technological procedures such as irrigation, cultivation and fertilisation lies in the water and nutrient supply of crops, i.e. the method of improving the water and air management, as well as the nutrient supply ability of the soil. However, there are production technological factors (e.g. population density, new hybrids or new varieties) which make it possible to utilise the favourable characteristics and the increased productivity of the soil in a better and more complete way.

### 3.1. 9. 3. 1. Correlation between irrigation and fertilisation

In the case of favourable nutrient supply, crops take up less water from the soil to produce one unit of dry matter. For this reason, the nutrient harmony re-established with fertilisation helps the better utilisation of the soil’s water stock. In order to achieve high quality and the highest possible yield, both factors need to be fulfilled separately and together in the quantity needed by the crop. In the case of favourable fertiliser supply, higher yield calls for higher water use in volume but lower water use in relative terms (Figure 50). The utilisation of fertilisers and the nutrients of the soil is the highest in the case of favourable moisture content.

9.1. ábra - Figure 50. The impact of irrigation and fertilisation on maize yield (Debrecen-Látókép)
3.2. 9. 3. 2. Correlation between chemical soil improvement and fertilisation

As a result of liming on acidic soils, the microbiological activity is becoming stronger. The correlation between the increasing lime doses and fertilisation is positive which has the highest value on brown forest soils and soils that do not contain high quantities of organic and inorganic colloids, especially until the level of half-dose liming. In the case of soils which contain higher amounts of clay and humus colloids, there is a steady correlation if full-dose liming is applied. The Ca uptake of crops increases. The amount of available phosphoric acid increases in the soil. Of microelements, only molibdenum is becoming easier to take up. The proportion of leaves increases in comparison with their stem and their total nitrogen content also increases which becomes possible due to the improvement of the soil’s nitrogen supply capacity. The amount of applied N and P can be reduced in 2-3 years after liming and the increase of the K active ingredient can be suggested. The reduction of the active ingredient proportion of nitrogen is recommended in order to prevent a decline in quality and lodging.

3.3. 9. 3. 3. Correlation between tillage and fertilisation

The soil type and the thickness of the productive layer – as well as its physical, chemical and biological characteristics – determine the success of the soil preparation of the produced crops, the method and efficiency of fertilisation, as well as the interactions of these factors. The procedures of tillage are in close correlation with the method and time of fertilisation. The interaction between tillage and fertilisation is determined by the extent of how much the nutrient supply of the soil changes as a result of cultivation. In areas with low precipitation, the water management of the soil, as well as the efficiency of fertilisation improve if proper cultivation is carried out. On heavy meadow soils, the physical condition of the soil affects the effect and successfulness of fertilisation.

During the mobilisation of the soil nutrients, the efficiency of fertilisation somewhat decreases. The difference in maize yield decreases with the increase of fertiliser doses depending on the tillage method. After the radical deepening ploughing, the impact of similar quantity of fertiliser will be lower than in the case of moderately deep ploughing.

9.2. ábra - Figure 51. Correlation between cultivation and fertilisation
3.4. 9. 3. 4. Correlation between plant number and fertilisation

There is a close positive correlation between plant number and fertilisation. The yield surplus caused by fertilisation increased to a certain point with the increase of plant number (Figure 51). Higher plant number will result in yield surplus only in the case of fertilisation. The possibility of increasing the maize plant number is in close correlation with the extend of nutrient supply and soil productivity.

9.3. ábra - Figure 51/b. Correlation between fertilisation and plant number

4. 9. 4. Basic principles of nutrient supply

4.1. 9. 4. 1. Based on experience and observation
Usually, the observations of experienced professionals, as well as the conclusions drawn from their observations can be found in crop production books. The data of the accurately kept plot register could draw one’s attention to certain connections with regard to the given plot in a multi-year relation following a proper evaluation. The modern statistical processing provides an opportunity to analyse the fertiliser effects. Smaller or larger deformations can be observed on crops suffering from under- or overfertilisation in comparison with harmoniously fertilised crops. The determination of the nourishment disorders of crops calls for a great expertise; therefore, visual diagnosis is often supplemented with plant and leaf analysis in order to draw the final conclusions.

Possible deficiency symptoms include the following:

• Totally ruined population at the seedling stage.
• Greatly stunted growth of crops.
• Typical leaf deformations appearing at various points of the growing season.
• Internal abnormalities.
• Late and abnormal ripening.
• Yield differences that are in accordance with the leaf symptoms and those which are visible even without them.
• Weak produce quality.
• Yield decrease.

In the field, it is often difficult to distinguish the various types of nutrient deficiencies. Sometimes the symptoms of various diseases or the damage done by insects or even water shortage itself are similar to nutrient deficiency symptoms.

4.2. 9. 4. 2. Based on the nutrient balance

In the nutrient balance, the items of nutrient sources and nutrient losses are listed against each other and the balance is evaluated per item and as a whole. During the calculation of the balance, every factor which leads to the increase of decrease of the nutrient stock of the soil has to be taken into consideration. The nutrient balance is a method developed in order to determine the nutrient demand of the planned yield. Furthermore, this method can also be used in the calibration of crop and soil analysis results. The methods of nutrient balance calculation are different depending on the purpose of use.

Usually, a nutrient balance refers to the difference between the amount of nutrients withdrawn by crops and the applied quantity of fertiliser active ingredient. However, the input and output sides of the real nutrient balance consists of many more items.

For example, the nutrients which are formed and left at a farm should also be considered on the input side, while the output side ought to include the nutrient losses, too.

Input sources

• used fertilisers
• organic fertilisers (farmyard manure, compost, secondary products of plants, industrial and communal wastewaters and sewage sludge)
• the nutrient content of irrigation water
• N binding bacteria
• N binding legumes
• atmosphere
9. Nutrient management

- sowing seed
- mineralisation

Output items
- plant uptake
- leaching
- erosion
- denitrification
- other atmospheric volatilization
- fixation

Levels of preparing a nutrient balance
- The nutrient balance of a given plot (whole balance, simplified balance, balance for one or several nutrients)
- Nutrient balance of the crop production branch or division (whole balance, simplified balance, balance for one or several nutrients)
- Nutrient balance of the farm (whole balance, simplified balance, balance for one or several nutrients, actual farm balance)
- On a regional level
- National nutrient balance

4.3. 9. 4. 3. Based on the adjustment of the solution concentration

Concentration adjustment is considered to be a limiting value method. The first step is to assume a certain soil solution concentration regarding the given element above which the fertiliser effect is hardly to be expected. The fertiliser dose should be determined in order to maintain this value.

Nowadays, the basic principle of this method is less used in fertilisation specialised consultancy systems.

4.4. 9. 4. 4. Based on plant analysis

The analysis can be performed on the whole plant or only parts. The quantity of a given element in the crop also depends on the crop’s level of supply with other nutrients. The ions of nutrients could mutually block or facilitate each other’s uptake. In order to determine crops’ level of nutrient supply, it is not enough to determine the concentration of each nutrient in the crop, but their quantities compared to each other, i.e. the nutrient proportions should also be calculated. In order to evaluate the level of nutrient supply, the development level of the population, i.e. the condition of crops should be considered. The reason why the supply level is different than the optimal level could be plant disease, intoxication or agrotechnical imperfection which occur independently of crops’ nourishment level. The concentration of each element could change depending on crops’ physiological age and the crop species. However, the detected concentration values remain easy to interpret if the sampling guidelines are accurately followed, as the each plant optimum is determined for the given species, crop part and development phase. It follows from the different nutrient uptake ability of crop species and varieties crops which have weaker nutrient uptake ability need a higher level of supply of the given nutrient in order to reach the optimal nutrient content.

The point of the limiting value method is that crop samples are taken at previously determined development stages and their element concentrations are determined. Using the tables in the specialised handbooks, it is verified whether these nutrient contents actually conform to the optimal values. If the supply level of any nutrient is worse than optimal, it has to be revealed what caused this weak supply level. If it was really not
caused by the improper nutrient supply of the soil, then the application of the given nutrient as fertilisation could make up for the deficiency. The weak nutrient supply of the soil can also be caused by drought. In cases like this, soil analysis results could be of great help.

If both the soil and plant analyses show that nutrient replenishment is needed, the amount of nutrient needed to stop nutrient deficiency should be determined.

4.5. 9. 4. 5. The nitrogen minimum method

The need to apply nitrogen in accordance with the crop’s demand, considering all aspects which influence the N supply of crops and the N supply ability of the soil is an issue of both economicalness and environmental protection. Primarily, crops take up nitrogen from the soil in the form of ammonium and nitrate ions, the quantity of which significantly fluctuates in accordance with the changes of temperature, soil moisture and the biological activity of the soil. In order to evaluate the N supply ability of the soil, the amount of exchangeable nitrogen forms and those present in the soil solution can be extracted from the soil with salt solutions.

In consultancy systems, the amount of N fertilisers to be applied is determined on the basis of knowing the quantity of mineral N in the soil.

By using this method, it is assumed that the mineral N content of the soil expresses the N quantity available for the plant, formed as a result of the mobilisation and immobilisation processes going on in the soil in a given period. In order to determine the mineral N content of soils, it is necessary to take average samples with utmost care and prepare them for chemical analysis. The obtained result is mainly affected by the time and method of sampling.

The time of sampling has to be close to the sowing dates of spring-sown crops; as well as the beginning of the vegetation in the spring in the case of autumn-sown crops. In order to perform the soil analysis, an average sample has to be prepared which is combined from 15-20 partial samples taken from 20-30 cm depth. Despite the fact that the impact of N fertilisation can be well observed in the upper 25-30 cm deep soil layer, it is necessary to determine the N content of at least the 0-60, 0-100 cm layers, or, in certain cases, even that of the 0-120-150 cm layers in order to evaluate the N stock of a given area.

The nitrogen fertilisation method based on the measurement of the mineral N content of soils became widely used in the agricultural practice mainly in the USA, Canada and Western Europe.

4.6. 9. 4. 6. Using yield simulation models

4.6.1. 9. 4. 6. 1. Empirical models

In specialised fertilisation consultancy systems, production correlations set up on the basis of the results of field experiments are used. In order to develop these so-called empirical or statistical models, the correlation of yields obtained in the experiments and certain measured variables are determined with statistical methods (correlation and regression analysis). Yields are expressed with correlations quantified with regression coefficients of the given variables. These values are obtained with linear or non-linear fitting to the values measured in the experiments. However, these correlations slightly reflect the mechanism of the dynamic operation of the system or they do not reflect it at all.

4.6.2. 9. 4. 6. 2. Dynamic yield simulation models

It is the interest of farmers to achieve and maintain the highest possible profit level, as well as to increase profits for years or decades. The consideration of the temporally and spatially changing values of the multitude of different factors poses a major problem. Yield simulation models are widely used around the world in the solution of such problems. Yield simulation models are mechanistic models consisting of mathematical correlations describing the processes which determine the behaviour of the system. These models are developed by dividing the system to its elements, quantifying its main processes and mechanisms and rebuilding it. By using this system, yield can be estimated in the case of various weather conditions, soil conditions, varieties, agrotechnics, etc. The amount of organic and artificial fertiliser needed for the realisation of the desired yield, as well as the rate of fertiliser application can be estimated with consideration of the given conditions.

4.6.3. 9. 4. 6. 3. Decision preparation systems
The integration of yield simulation models with the so-called expert systems is becoming increasingly widespread. By means of this integration, it is possible to develop decision support systems which are increasingly demanded in the agricultural sector. Databases of soil characteristics, area use, weather and other information or regional level embedded into an expert system can be integrated with yield simulation models that can be connected to GIS systems and by using the alternatives provided by GIS, it is possible to build easy-to-use regional decision preparation systems. This way, the problems can be drafted in the most appropriate way, the data can be easily and quickly accessed and efficiently used for decision preparation.

As a result of the fundamental validity of the knowledge in yield simulation models, as well as the process focus and interpretation of this knowledge in quantified, mathematical correlations, these models can be widely used in research, education and practice.

5. 9. 5. Nutrient supply of organic farming

In organic farming, self-regulating, i.e. strict regulations determine the nature and quantity of substances which can be used in nutrient replenishment. As a matter of course, restricted nutrient replenishment results in lower yields, but the aim is to produce outstanding quality products for human consumption without the use chemicals and environmental pollution. This form of farming strictly limits and prohibits the use of synthetically produced fertilisers.

In organic farming, fertilisation can only be performed on the basis of the nutrient balance of the soil. It is the primary principle of organic farming that the amount of organic substance, macro- and micronutrients that is returned to the soil during production must not be more than what is withdrawn by plants. At the same time, it is considered to be important that soil productivity should not decrease, but it should increase along with its biological activity.

6. 9. 6. Calculation of the amount of fertiliser active ingredient

1. Determining the soil type of the farm (plot) and classification into production site categories
2. Planning the yield of the plant to be produced on the plot based on the yield of the preceding 5 years
3. Determination of the level of nutrient supply (N, P, K) based on soil analysis data
4. Determination of specific active ingredient need based on the humus, P, and K supply of the soil
5. Determination of the fertiliser active ingredient need related to the planned yield
6. Corrections
7. Method and timing of fertilisation

7. 9. 7. Environmental aspects of nutrient supply

The irrational use of nutrients could result in the damaging of certain environmental elements. The environmental damages can be avoided if the following factors are taken into consideration during the calculation of the fertiliser doses: the level of nutrient supply of the soil, plant needs, planned yield, proper application timing and breakdown.

The environmentally damaging impacts can be counterbalanced by

- proper transport and storage,
- preparing soil analyses,
- determining the mineral N content of the soil,
- liming on acidic soils,
• using slow acting fertilisers,
• applying the amount of active ingredient which is adjusted to the plant needs,
• professional broken down dosaging (N),
• blocking erosion processes,
• using proper (soil protective) agrotechnical solutions,
• production site-specific nutrient replenishment.

8. 9. 8. Precision, production site-specific fertilisation

A plot cannot ever be considered to be homogeneous: the physical and chemical characteristics of the soil and the terrain can be rather versatile within a certain plot. Plants have different vital circumstances in the different parts of a plot. Precision and location specific farming, as well as the consideration of diversity are necessary in order to provide the proper vital conditions for plants. The smallest unit of farming is the treatment unit which is homogeneous from the aspect of the given characteristic. Homogeneous intervention is made within each unit.

8.1. 9. 8. 1. Precision collection of soil data

The prerequisite of production site-specific fertilisation is the soil sampling carried out in the sampling units properly delineated in accordance with the heterogeneity of soil characteristics. The data collected this way contain the geographical coordinates of the measurement location and the measured data. With the help of the GPS, it is possible to repeatedly take samples from the same place; therefore, the changes of nutrient management can be measured and the results shown on a map.

Delineating the sampling units:
• Based on available information (yield map, soil map, EC map)
• Systematic or grid sampling (Figure 52)

Measurement of the level of nutrient supply with continuous sampling:
• Measuring the electrical conductivity (EC) of the soil (Figure 53)
• Spectroscopic measurement in the near infrared range (NIR).
• With ion-selective membranes

9.4. ábra - Figure 52. Systematic or grid sampling
9.5. ábra - Figure 53. Measuring the electrical conductivity (EC) of the soil

8.2. 9. 8. 2. Production site-specific fertilisation

The planned production and the amount of nutrients to be applied for each treatment unit has to be determined. The larger the database of the precision nutrient management is, the more exact yield planning can be performed. Precision fertilisation is done on the basis of a previously prepared plan with DGPS (Differential Global Positioning System). The dose of the given position is set by the quantity regulator controlled by the
board computer. The process can be supervised on the display to see whether the spraying is done in accordance with the program.

During side-dressing, the amount of nutrients to be applied can be determined based on the nitrogen sensor analysing the plant conditions. In this case, no preliminary plan has to be prepared. The applied dose is shown on the basis of the sign sent by the sensor.
10. fejezet - 10. Production site protection, protection against erosion and deflation

1. 10.1. The importance of production site and soil protection

Of Hungary’s natural endowments, the country’s croplands are of special importance. Primarily, land owners and land users are responsible for maintaining soil productivity, but this responsibility extends over the state and the society. It is the common task of agriculture and environmental protection that the damages done by land use should not escalate towards the surface and subsurface waters, as well as the atmosphere and the living resources. As a result of the damages, soil productivity decreases which will deteriorate yield quality, decrease yield and the profitability of farming is becoming endangered that will further narrow down the opportunities of farmers. The low standard of production culture of those who became farmers due to some external force represents a huge risk. The lack of protection increases degradation processes on the originally highly productive soils (Figure 54).

More than half of the agricultural land is damaged by some soil degradation process:

- Erosion (Figure 56)
- Deflation
- Soil acidification
- Salinisation
- Surface water
- Soil compaction
- Secondary salinisation
- Flood
- Base rock getting on the surface

10.1. ábra - Figure 54. Soil degradation processes in Hungary
10.2. ábra - Figure 55. 40% of Hungary’s area is endangered by erosion

In Hungary, the area used by agriculture and forestry decreased by 345 000 ha in the last 40 years. Due to building and road constructions and various investments, this process does not stop. In addition to conforming to the Act of Land and the Environmental Protection Law, the withdrawal of areas less valuable for agriculture represents an opportunity to save valuable areas. Land withdrawal mainly affected ploughlands and grasslands. The soil of the withdrawn areas loses its productivity forever. This is an irreversible process; therefore, it calls for thorough consideration.

The production area is in constant reduction due to the following factors:

• Urbanisation,
10. Production site protection, protection against erosion and deflation

- Industry expansion,
- Surface mining,
- Settlement development,
- Infrastructure development,
- Recreational development,
- Waste disposal.

2. 10.2. Land consolidation

Land consolidation is the basis of agronomical soil protection, as it is the carefully considered method of using lands. The method of use is called land use type. During the establishment of the proportion and location of the different land use purposes (ploughland, meadow, pasture, garden, forest), it has to considered whether it is possible to preserve soil fertility.

Ploughland: lands in agricultural use that is cultivated on yearly basis. It can be established on areas with slopes lower than 17%. Significantly divided areas cannot be used as ploughland. Advanced soil decay could an obstacle to developing a ploughland. The soil protection value of ploughlands is determined by the spatial and temporal dimension of crop coverage, the amount of root mass and crop residues, as well as their quality, in addition to whether a soil protective tillage method is used (Table 3). One of these methods is when a land is regularly used as a grassland. The produced crops have different soil protective effects, as it can be seen in Table 3. Based on the duration and extent of soil coverage, the following categories were established.

10.1. táblázat - Table 3. Classification of the produced crops based on their soil protection effect.

<table>
<thead>
<tr>
<th>Soil protection effect</th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good soil protection effect</td>
<td>ley, mown grass, perennial legume fodder crops.</td>
</tr>
<tr>
<td>Medium soil protection effect</td>
<td>autumn-sown cereals, autumn and spring forage mixtures</td>
</tr>
<tr>
<td>Weak soil protection effect</td>
<td>legumes</td>
</tr>
<tr>
<td>Bad soil protection effect</td>
<td>root crops</td>
</tr>
</tbody>
</table>

Plantations: Production of perennial plants planted in a permanent location. The limiting factor of establishing a plantation could be the lack of soil cover or the thin fertile layer due to erosion damages, the heterogeneous soil quality deteriorates the production conditions. Before planting, it is worth carrying out shallow tillage and deep loosening in order to improve the water management of the soil instead of the 50-80 cm deep ploughing with a rigol plough due to the risk of B level getting onto the surface, as it has unfavourable water management characteristics. The southern, southwestern parts of slopes lower than 30% are suitable for grape and fruit production. The basis of the soil protection of plantations is the fact that they are planted perpendicularly to the slope. By building terraces, the angle of inclination of the slope decreases, thereby preventing the runoff of irrigation water. In the case of grape, establishing terraces on slopes steeper than 12% is an indispensable condition of safe production, while the steepness is 17% in orchards. Green manure crops or grass sown in row spacings decrease erosion.

Grassland: Meadows and pastures overgrown with perennial grasses and legumes, which is an outstanding method of utilising slopes and strongly dissipated areas. Areas with 17-35% steepness and mostly northerly exposure can be utilised this way. The soil protection effect of grasslands is permanent, the high plant number means a huge root mass, which is of special significance from the aspect of soil protection. Grasslands provide constant coverage. In order to provide the proper soil protection effect, a closed plant population has to be
present throughout the whole year. This can only be realised if the grass can be maintained in the proper culture status during the vegetation period, with special regard to the late summer drought period. The properly handled, closed grassland provides permanent protection of the slope soil.

Forest: Contiguous woody plant community of at least 0.25 hectare. If the slope is steeper than 35%, the area must be forested by all means. The mains aim of establishing a forest are soil protection and the improvement of environment quality. Forestation is indispensable in areas unsuitable for grasslands, on steep slopes and in rainwashes. Forest strips, tree groups, shrub strips provide protection to areas used in different ways.

3. 10.3. Plot development

During plot development, the ploughland is divided to nearly equally sized, possibly regular shaped, easily accessible cultivation units. Plot development is a task which is related to the development of soil use types. On slope areas, plot development can be carried out with the preference of soil protection duties. A ploughland plot is the naturally bordered smallest unit involved in agricultural production on which the same agrotechnical procedures are performed. Developing plots larger than 100-150 ha is not justified, as the soil of areas of such extension has heterogeneous productivity, their water cycle is unbalanced, resulting in increased damage done by erosion and deflation. Furthermore, large machinery needs to move around a lot on large plots which results in soil compaction.

3.1. 10.3. 1. Guidelines of plot development

During the establishment of plots, the non-removable objects and public roads should be considered. At the same time of establishing roads, the tree rows, shrub strip and other protective strips have to be designated and their direction should be the same as the roads to be built. On slope areas, forest strips have to be established along the layer lines.

The development of the produced plants should be homogeneous, the knowledge of genetic soil maps is necessary. The aim is to not to have significant differences in production technological efficiency on 80% of the plot's area. Landscaping is necessary occasionally in order to homogenise the production site. The shape and size of the plot should make it possible to handle it as a separate water cycle unit, if the moisture conditions are homogeneous on the whole plot, the machines perform in the same quality. The length and width ratio of the plots should be between 1:1.5-3 on flat areas and slight slopes in order to conform to the mechanisation and soil protection requirements.

3.2. 10.3. 2. Guidelines of plot development on slopes

Depending on the evenness of the slope terrain, the longitudinal side of the plots need to be developed along the layer lines, perpendicularly to the slope direction. Also, the direction of cultivation should be the same, or else the area will suffer erosion damage similar to what can be seen in Figure 56. Ditches and crevices on slopes have to be filled up in order to be able to cultivate them, as they might contribute to erosion.

On slopes, plots should be developed perpendicularly to the direction of the slope, the width of the plot has to be developed in a way to prevent erosion damage. The water running down a slope of short flowage cannot speed up enough; therefore, it will not have enough energy to carry soil parts with itself. If the width is larger than the critical slope length, the strength of the running water increases the limit value.

10.3. ábra - Figure 56. Erosion damage in the case of crop production of hill – valley direction
The optimum length of plots in hill areas is 1000-1500 m. Plot length under 1000 m increases the cost of operating machinery. Too long working path can result in organisational problems. Usually, plot length is limited by natural or artificial obstacles. Due to soil protection purposes, it is practical to develop strip sowing on plots in hill areas. Production of crops of different protection effect on the same plot in alternating strips is recommended. The strips should be parallel to each other. Strip sowing is extensively used in foreign countries, while it is not a widely applied method in Hungary (Figure 57). The quantified guidelines of plot development are shown in Tables 4 and 5.

10.4. ábra - Figure 57. Strip sowing on slopes

Source: http://www.thefreedictionary.com/strip-copping

10.2. táblázat - Table 4. Guidelines of plot development on slopes: plot size per slope category

<table>
<thead>
<tr>
<th>Slope category</th>
<th>plot size</th>
</tr>
</thead>
</table>

Created by XMLmind XSL-FO Converter.
10. Production site protection, protection against erosion and deflation

<table>
<thead>
<tr>
<th>Slope category</th>
<th>Plot width</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-12%</td>
<td>20-45 ha</td>
</tr>
<tr>
<td>12-25%</td>
<td>10-30 ha</td>
</tr>
</tbody>
</table>

10.3. táblázat - Table 5. Guidelines of plot development on slopes: plot width per slope category

<table>
<thead>
<tr>
<th>Slope category</th>
<th>Plot width</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-12%</td>
<td>200-300 m</td>
</tr>
<tr>
<td>12-17%</td>
<td>100-200 m</td>
</tr>
</tbody>
</table>

4. 10.4

4.1. 10.4. 1. Development and forms of erosion

Fertile soil carried biological life and it is the main stage of vegetable and animal associations, as well as human life and the source of production activities (agriculture, forestry, raw material production, etc.). Soil is a special resource which is in constant renewal if there are no harmful interventions. In the processes of natural soil life, the degradation and building of natural substances are balanced. It is our obligation to protect the soil from all types of damage, to preserve its quality, quantity and the condition of its optimum productivity. It is the task of soil protection research to clarify the reasons of degradation, as well as to work out and properly develop the complex biological, agrotechnical and technical solutions of soil protection. Soil erosion is soil degradation caused by water which can be developed under natural plant coverage in undisturbed soil in natural regions under certain circumstances. This process is called geological erosion, which is a slower process that needs more time to develop. Impacts caused by humans such as deforestation, ploughland cultivation and animal husbandry cause accelerated erosion which leads to the total deterioration of the fertile layer and the base rock getting onto the surface in a short amount of time, depending on the terrain conditions. The most endangered areas are the ploughlands which are seated on alluvial, loessy subsoils in the North Hungarian Mountains which has versatile terrain.

Drop erosion: crumb disintegration as a result of the mechanical impact of raindrops (Figure 58).

Aspects affecting the extent of drop erosion:

• the size of water drops from above
• amount of water in a unit of time, i.e., the intensity of precipitation
• duration of rainfall
• moisture conditions of the soil, water uptake, permeability and retention ability of the soil
• soil structure and compactness
• extent of crop coverage

Strongly hitting drops destroy soil particles on the surface as illustrated in Figure 3. The torn parts get into the solution. The longer the strong physical impact takes, the more the soil surface becomes silted. The resistance ability of soil crumbs depends on the genetic soil type and humus content.

Drop erosion is reduced by the vegetation on the surface. The higher the crop coverage is, the more water the foliage can retain, thereby reducing the impact energy and protracting the contact between the drops and the soil surface.

10.5. ábra - Figure 58. Drop erosion
Veil erosion: once the upper soil layer reached its maximum water capacity, it is no longer capable to let water through at the same rate as it reaches the surface and a veil-like coverage will be developed in the area, the consequence of which is shown in Figure 59. Due to the unevenness of the soil surface, water will accumulate in dips, containing valuable organic substances dissolved from the soil. The accumulated water begins to move towards the slope direction, it forms streamlets and flows towards the next dip. This phenomenon can also appear during snow melting, when the still frozen soil is not able to absorb the quickly melting snow.

Factors affecting the extent of veil erosion:

- speed of permeation
- intensity of precipitation or irrigation, rate of snow melting
- unevenness of soil surface
- extent of crop coverage, amount of crop residues

10.6. ábra - Figure 59. Veil erosion

Furrowed erosion: the water collected in a furrow cuts an increasingly deep bed while carrying along increasing amounts of soil. The depth of the furrows forming this way is usually the same as the cultivation depth (Figure 60), especially if there is a compaction layer at that given depth. Nevertheless, the more compacted level B (which is more resistant to erosion) can also be an obstacle. The streamlets flow at an increasing speed, following the curves of the terrain and collecting an increasing amount of water. In the case of cultivation of mountain-valley direction, water mostly finds its way in the track of the cultivation tool.

Factors affecting the extent of furrowed erosion:

- water saturation of the soil
- quantity and duration of rainfall
- length, exposure, shape and steepness of the slope

10.7. ábra - Figure 60. Furrowed erosion
Ditch erosion: rainwashes forming as a result of the joined water amounts of furrows. These ditches are deeper than the cultivated layer and they penetrate the level B of the soil profile (Figure 61). The ditches forming this way are obstacles to cultivation tools. The abyss-like terrain obstacles make it possible to access the plot and to perform uniform cultivation. Over time, rainwashes widen enough to become valleys which make quick runoff possible.

Factors affecting the extent of ditch erosion:

- length of runoff line
- steepness of the slope
- slope type
- microterrain

10.8. ábra - Figure 61. Ditch erosion

Further consequences of erosion damages occurring on slopes are below:

Sedimentation: deposits of silted soil particles transported by water at the bottom of the slope.

Eutrophication: the appearance of organic and inorganic nutrients in living waters, dissolved and transported by water. Large amounts of dissolved nutrients upset the balance between photosynthesis and respiration in living waters, thereby causing severe environmental damage.

4.2. 10.4.2. Alternatives of protection against erosion
Protection against erosion needs to be extended to the whole catchment area. Any intervention in the catchment area can only be planned on the basis of the factors eliciting erosion and affecting its extent. It is important to use cultivation methods whose effect provides permanent protection of the fertile soil both during and outside the growing season. Soil protection management is a complex technological system which involves the elements of biological, production technological and technical interventions which can be applied under the given ecological circumstances. In accordance with the general expectation, the opportunities provided by biological and agronomical protection has to be utilised to the greatest possible extent and the development of severe damages needs to be prevented.

Biological protection means the soil protection effect imposed by the organisms living on an in the soil. Crops grown on slopes protect the soil surface from drop erosion with their foliage as they retain a large amount of water and slow down the development of a critical sized surface water veil. It is worth producing densely sown crops which cover the soil for a long period. The tools of increasing green mass can also be effectively used for increasing root mass. Planted grasslands and perennial fodder crops are good examples of the favourable protection effect, as there are no significant erosion damage under their populations even in the case of increased exposure. During the degradation of root and crop residue mass, soil life becomes more increased, microorganisms propagate and their activity results in improved soil structure and water management. The preservation of organic matter contributes to the formation of soil crumbs which are more resistant to drop erosion. In addition to growing crops with soil protection effect and using crop orders which adapt to terrain circumstances, the proper choice of soil use types adapted to terrain configurations (grasslands, shrubberies, forests) could also be helpful.

The most important procedures of agronomical protection are connected to cultivation. Any tools and methods which reduce or postpone the runoff on the surface and increase the water absorption capacity of the soil are listed here. The first group includes the special tools which form the soil surface, such as the rollers increasing the roughness and water retaining ability of the surface, the cultivators developing a protective surface, the ridged ploughing and the furrowed cultivation.

The second group involves the procedures which reduce runoff by means of increasing the soil’s absorption capacity: various tools and solutions of deep tillage, loosening tools (heavy cultivators, soil splitters, deep looseners).

The direction of cultivation and sowing has to be designated perpendicularly to the slope along the layer lines (Figure 62). If the direction of cultivation is the same as the mountain-valley direction, it reduces the effectiveness of even the best cultivation tools, thereby increasing the chance of accelerated erosion processes.

In addition to cultivation, the procedures which increase the green mass of and the coverage provided by crops also belong to agronomical protection. Crop nutrition adapted to ecological endowments and crop needs improve soil protection indirectly. As a result of erosion, the productivity differences in the plots impose a special duty in implementing proper crop nutrition. The rainwashes which formed as a result of erosion can be caught using technical solutions and they will prevent further damages from happening (Figure 63). The procedures of protection against erosion and their tools are summarised in Table 4.

10.9. ábra - Figure 62. Ploughing performed perpendicularly to the slope direction along the layer lines and ploughing performed incorrectly in the mountain-valley direction.
10. Production site protection, protection against erosion and deflation

10.10. ábra - Figure 63. Intervention against erosion, rainwash connection

10.11. ábra - Table 4. Procedures and tools of protection against soil er
5. 10.5 Deflation

Deflation: soil degradation caused by the surface forming impact of wind. The wind lifts the valuable soil particles of the fertile layer, transports accumulate them at a remote place. Therefore, nutrients valuable from the aspect of production will go to waste.

5.1. 10.5. 1. Factors eliciting and affecting deflation

In the physical sense of the word, deflation is basically determined by two complex factors: the speed and whirling of the wind and the exposure and length of the plot. Deflation is determined by the mechanical composition of the soil, as well as its structure, compactedness, organic matter content, moisture content and the roughness and coverage of its surface.

These factors appear in the production sites in a complex way with various dominance level, depending on the given natural endowments. Incomplete plant coverage, loose, dry and smooth soil surface, large plot size, strong wind and the lack of wind-breaking forest strips are the main factors which increase deflation risk. The soil structure is of fundamental importance in the development of deflation. In addition to sandy soils, dried out peat soils and completely degraded, dustified soils are also exposed to deflation risk. Usually, adobe and clayey adobe soils are more resistant in terms of the breakdown of aggregates; therefore, their deflation sensitivity is also lower; their aggregates are heavier than the independent soil particles; therefore, it is more difficult to remove them. In general soils whose organic matter conditions are better from the aspect of aggregate stability can resist wind damage. As a result of deflation, soil structure deteriorates and soil productivity decreases. The water capacity of the soil decreases and its drought sensitivity increases.

The repeated loss of finer soil particles constantly deteriorates soil productivity. On degraded soils with shallow fertile layer or a compacted layer, the thickness of the initially thin layer containing the nutrients and water for crops will further decrease as a result of wind damages. Usually, these processes are slow and their effect stay hidden for a long time, especially if the mixing procedures hide the signs which show the already present damages.

Factors eliciting deflation:

- wind speed and whirling
10. Production site protection, protection against erosion and deflation

• exposure and size of the deflation area

Factors affecting deflation:

• mechanical composition of the soil: sandy soils, dried out peat soils and degraded, dustified soils are the most endangered.

• soil structure and compactedness: adobe soils and clayey adobe soils are more resistant

• organic matter content of the soil: the aggregates of soils with good organic matter condition are heavier, they cannot be easily removed, unlike the soil particles which are torn off.

• moisture condition of the soil: soil particles get lifted off the dried soil surface more easily; in drought periods, the wind can transport an enormous amount of soil particles.

• roughness of the surface: soil particles get lifted off the ground easily if the surface is smooth

• crop coverage: the larger the spatial and temporal crop coverage of the area, the more it is able to protect the soil from the damaging impact of the wind.

The main reasons of deflation:

• deforestation,

• elimination of grasslands,

• soil use neglecting soil protection,

• deterioration of the soil structure,

• improper water management (drainage of bogs),

• higher proportion of areas potentially endangered by deflation (sand drift soils).

5.2. 10.5. 2. Protection against deflation

Deflation has always made farming on flat areas more difficult. Nowadays, the realisation of the necessity of soil protection and the various methods of soil structure protection make it easier to include the procedures of wind erosion reduction into tillage systems.

Protection against deflation becomes possible by means of modifying the eliciting and affecting factors. In addition to reducing the size of the plot exposed to wind speed and its deflation impact, there are numerous agrotechnical and cultivation elements which can be used. Although these methods are not able to totally stop deflation damages and they are of low effectiveness when used individually, but the simultaneous use of several methods could lead to success.

The establishment of meadow protecting forest strips eases deflation damages independently of the applied crop protection technology (Figure 64). However, this technology has a higher importance in drought years when there are less crop residues in the area after the produced crop. Meadow protecting forest strips reduce wind speed at a distance 20-30 times longer than their height; therefore, they limit the plot size which can be protected this way. They could also have a role in preserving the moisture content of the soil, as the evaporation losses also decreases with the reduction of wind speed. By retaining snow, the moisture content of the area increases.

10.12. ábra - Figure 64. Planting soil protection tree rows
10. Production site protection, protection against erosion and deflation

Artificial wind-breaks, mobile support sheets woven from willow-twiggs and sprigs could also reduce the damages caused by winds.

The change of land use for soil protection purposes, planting grasslands and forests – in harmony with other factors – provide permanent, but not generally applicable solutions against wind erosion.

Deflation damages can also be decreased by developing plot sizes which are optimal from the aspect of soil protection. The damage caused by wind can be eased by crops sown at different times, as well as their residues; strip or chessboard sowing and the protection of wind-sensitive spring-sown crops can be carried out with plants sown as a protective strip.

Also, soil improvement procedures can be used to replenish organic matters. By increasing the aggregate stability, it is possible to develop a structure in which the majority of crumbs are of 1-10 mm diameter and they are more difficult to remove, they only roll over or slide at a shorter distance.

Covering the surface with straw, manure, manure waste, turf, tree leaves, dry soil, sand, chalk and lime protects the soil against wind damages. As soil coverage prevents the soil from drying out, it also give protection against the destroying effect of rains due to its effect of reducing evaporation loss; therefore, the probability of the development of deflation-sensitive, dusty soil condition also decreases.

The shorter the uncovered period is, the lower the wind damage is. By reducing the wind speed close to the soil surface, the vegetation provides protection against deflation. After harvesting the main crops, the harvesting of middle and green manure crops can be taken advantage of by means of soil coverage. The surface protection effect can also be increased with growing more perennials – legumes, grasses – and spring-sown crops. Overgrazing should be avoided in order to protect pastures, as scarce crop coverage increases the possibility of degradation processes and deflation.

Soil protective cultivation has an important role in preventing deflation damages. Every cultivation method should be performed perpendicularly to the dominant wind direction, whenever possible. After each procedure that leaves the soil surface smooth, it has to be roughened and efforts must be made at making the surface wavy (with different harrows and rollers). One has to aim at ridged ploughing, too (Figure 66). If possible, primary tillage on sand drifts and mull soils should only be performed before sowing. Mulch tillage can also be preferred. In systems developed for areas exposed to deflation, procedures reducing wind speed and protecting the soil from being transferred by the wind need to be used. Leaving the crop residues on the surface or incorporating them into the shallow soil are practices which are becoming increasingly widespread (Figure 65).

10.13. ábra - Figure 65. Leaving the crop residues on the surface using by mulch tillage system and/or developing a wavy surface
The basic principle of the cultivation reducing deflation damages is that there should be as much crumb, so-called microaggregate and crop residues on the soil surface as possible. In order to prevent soil dustification, machinery combinations should be used which establish the soil condition needed by the crop in one turn and create a protective surface at the same time. The generally used plate ploughs and the strongly dustifying tools (spike-tooth and disc harrows, smooth rollers) should be avoided in these areas. At the same time, the different pulverisers which create a protective surface (mulch cultivators) and the furrow splitter sowing machines that provide steady performance also in the case of massive crop residues can be effectively used. On the Great Plain soils endangered by wind erosion, it is recommended to mount chisel-shaped tools onto the cultivators, since these make it possible to adequately pulverise the soil, but they do not turn it over and do not mix it. The main rules of protection against deflation and the tools of protection are summarised in Table 5.

10.14. ábra - Table 5. Procedures and tools of protection against deflation
10. Production site protection, protection against erosion and deflation

<table>
<thead>
<tr>
<th>Deflation prevention</th>
<th>Methods of prevention</th>
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<tbody>
<tr>
<td><strong>Reducing wind speed and plot size</strong></td>
<td>Placing mobile support sheets woven from willow-twigs and sprigs</td>
</tr>
</tbody>
</table>
| Planting meadow protecting forest strips | meadow protecting forest strips reduce wind speed at a length 20-30 times the tree heights  
they reduce the moisture loss of the plot soil |
| **Artificial wind-breaks** | planting grass and forests for soil protection purposes |
| **Change of land use due to soil protection** | strip or chessboard sowing of plants produced at different times  
protection of wind-sensitive spring-sown crops with plants sown as a protective strip |
| Development of optimum plot size | increasing soil aggregate stability with organic matter replenishment |
| Organic matter replenishment | covering the soil surface with plant residues, manure, peat, leaf  
the plant should cover the soil surface as long as possible  
production of intermediate or green manure crops after the harvesting of the main crop |
| Soil coverage | performing the tillage perpendicularly to the general wind direction  
developing a wavy surface  
crest ploughing  
primarily tillage before sowing on sand drift and mull soil  
mulch tillage  
prevention of the dustification of the soil surface |
11. fejezet - 11. Production site protection and improvement

1. 11. 1. Concept and tasks of soil improvement

Soil improvement is the collective of procedures which permanently increase soil productivity by eliminating certain soil imperfections or by establishing a previously missing favourable soil characteristic. Soil improvement tasks include the elimination of harmful phenomena resulting from high sand content, soil acidification, primary or secondary salinisation, soil structure deterioration and soil compaction, as well as the stopping and reversing of negative processes.

2. 11. 2. Improvement of saline soils

In Hungary, soil salinisation affects around 3.2 million hectares (Figure 66.). Attempts at improving saline soils were made already in the 18th century. The improvement of saline soils can only be successful if we consider the reason of salinisation and the improvement itself is directed to the elimination of this reason.

11.1. ábra - Figure 66. The location of saline soils in Hungary

2.1. 11. 2. 1. Types of saline soils

In the case of solonchak soils, salinisation is caused by water-soluble Na salts accumulating in the upper soil. The soil profile can be seen in Figure 67. In meadow solognec soils, salinisation is caused by Na ions adsorbed on the surface of colloids. The soil profile can be seen in Figure 68. The thickness of the leached upper soil can be different. Solonchak-solognec soils show the features of the two previous basic types jointly. Figure 69 shows a profile of such soil type. Secondary saline soils represent the soils in which salinisation results from human activities.
11. Production site protection and improvement

11.2. ábra - Figure 67. Solonchak soil

11.3. ábra - Figure 68. Meadow solognec soil

11.4. ábra - Figure 69. Solonchak – solognec soil

2.2. 11. 2. 2. Improvement of saline soils

Water management of saline soils:

The main source of salt accumulation is the saline groundwater elevated close to the surface.

Salinification can be stopped by stopping groundwater elevation, subsoil piping or open ditch drainage is a solution on meadow solognec soils. In areas prone to drainage water accumulation, the drainage of surface water has to be solved.

Tillage of saline soils:

The tillage of meadow solognec soils cannot be deeper than the thickness of the washed level "A", so that the less favourable soil will not get onto the surface. Ideally, deep loosening should be repeated every 3-4 years.

Classification of saline soils based on their relation to groundwater:

Group 1: The groundwater elevation reaches the upper soil layer.

The salt content of the surface is higher than 0.2%.
11. Production site protection and improvement

Improvement: drainage, washing with irrigation water, chemical improvement.

Group 2: The groundwater occasionally elevates into the upper soil layer.

The salt content of the surface is less than 0.2%.

Improvement: drainage, chemical and mechanical improvements are not always necessary.

Group 3: The groundwater sinking tendency prevails.

The salt content of the surface is only remainder. The exchangeable Na content is less than 10-15%. The washed layer is deeper than 15-20 cm.

Improvement: surface drainage, cheaper chemical and mechanical improvement.

Classification of saline soils from the aspect of chemical improvement:

1. Non-calcareous, acidic-neutral soils: They can be improved with liming and spreading of calcareous subsoil.

2. Non-calcareous, weakly saline soils: They can be improved with the mixture of lime and gypsum.


Substances which can be used to chemically improve saline soils:

• CaCO3 containing substances (loess, limestone powder, sugar factory caustic sludge, bog lime) until 7.2 pH.

• CaCO3 and CaSO4 * 2H2O containing combined substances between 7.2-8.2 pH.

• CaSO4 * 2H2O, CaCl2, FeSO4, AlSO4, lignin and sulphur containing substances above 8.21 pH.

3. 11. 3. Improvement of acidic soils

Soil acidification is the most widespread soil degradation process in Hungary, affecting around 2.3 million ha (Figure 70).

11.5. ábra - Figure 70. Location of acidic soils in Hungary

3.1. 11. 3. 1. Reasons for soil acidification
The alkaline and neutral decay products which are the results of soil formation are leached from the upper soil and the acid production processes will become dominant. The factors determining this process are constantly present, resulting in soils losing significant amounts of calcium.

Of climatic factors, precipitation affects the process of degradation. Large amounts of rainfall make the chemical deterioration of the soil and the washing out of the easily soluble products more intensive. The physical characteristics of soils degrade with the increase of soil acidity and its unsaturated character. The majority of our acidic soils – especially those that contain large amounts of organic and inorganic colloids – can be characterised by unfavourable structure, compactedness, airtight conditions, and low water intake capacity. The water intake characteristics of acidic soils are made more difficult by the fact that they are prone to surface silting, deliquescence and cracking due to the adverse colloidical features resulting from their unsaturated character. Therefore, the closing of the soil surface could reduce the water intake and air exchange of soils to the minimum. Furthermore, it is a frequent consequence of these processes that the majority of crop germs perish after sowing due to the cracking resulting from the compaction, airtight conditions or surface water pressure. The accumulation of the biologically important elements is weaker under trees and forests and the washing loss and acidification of the soil is more intensive. Due to the drainage losses in slope and hilly areas, the amount of water seeping into the soil is lower. The base rock rich in carbonates inhibits soil acidification. Acid soils are formed on acid rocks rich in quartz.

As regards anthropogenic factors, agricultural activities greatly increase this phenomenon. The deeper the tillage is, the higher the extent of leaching is. The acid substances originating from the atmosphere make soils acid. In areas with more rainfall and on irrigated soils, Ca leaching and soil acidification become more intense.

The increased production of crops is accompanied by the increasing loss of soil Ca. The amount of Ca withdrawn from the soil with yield is between 0.3-0.8 t/ha each year, depending on the Ca uptake of crops, which is a rather significant amount in the case of soils containing low amounts of Ca. The regular application of fertilisers in the soil accelerated the acidification and repeated acidification processes of low adsorption capacity and base saturation soils which were subject to liming procedures of meliorative scale. This acceleration especially affected the mildly acidic soils, resulting in stronger acidification that was even harmful from the crop physiological aspect.

The favourable effect of Ca on soil productivity, as well as the yield quantity and quality of the produced crops has a much wider range than what can be expected during the simple replenishment of some other nutrient. The application of Ca is at least as important from the aspect of the nutrient solubility in the soil and the proper nutrient supply of crops as in changing the unfavourable acidity and pH conditions of the soil.

3.2. 11. 3. 2. Methods of improving acidic soils

With liming: During liming, Ca ions and substances with saline effect are applied on the soil, thereby increasing the Ca concentration and the pH of the soil.

Methods of liming:

• Meliorative liming: Chemical improvement of acidic soils or soils whose upper layer is acidic as a result of leaching.

• Maintenance liming: Low dose liming improving the efficiency of meliorative liming and preventing the recurrence of soil acidity.

• Lime fertilisation: Improvement of the Ca supply of the regularly cultivated soil layer, preventing the development of soil acidity harmful from the aspect of production.

3.3. 11. 3. 3. Determining the liming dose

Research and practical findings both show that the hydrolytic acidity value of 8 widely referred to as critical is the limit value of acidity from the crop production aspect in the case of sandy, raw alluvial and brown meadow soils, but basically in each soil that contains small amount of organic and inorganic colloids. Above this value, crops sensitive to acidity – e.g. alfalfa, sugar beet, legumes, etc. – produce fewer yields and their production might not be safe either. In addition, the easily soluble nitrogen and phosphorus content of the soil is also shown to decrease.
Since numerous research findings show that it is possible to measure hydrolytic acidity whose value is unfavourable from the aspect of crop production and the nutrient supply ability of the soil even in the case of a favourable pH value, the more accurate determination of the necessity of soil improvement and the amount of CaCO3 needed for improvement calls for the hydrolytic acidity value. More specifically, the widely present exchange acidity (y2) which shows a dangerous extent of acidity for crops should be preferred by all means. The reason for the lower yield of alfalfa produced on sandy soils, raw alluvial soils and brown forest soils which provide hydrolytic acidity values above 8 is the scarce crop stand and the resulting early and strong weed infestation. The majority of the alfalfa seed sown into soils with this high level of acidity dies even during germination and the initial development stage. Therefore, in order to improve sandy, raw alluvial and brown forest soils, the amount of CaCO3 to be incorporated into the soil makes it possible to reduce the hydrolytic acidity below 8. Based on the research findings, reaching this level in the case of the above mentioned soils is possible even with the so-called “half-dose liming” which means half of the amount calculated on the basis of the performed soil analyses (y1 and KA). The yield increasing effect of higher amounts of CaCO3 incorporated into the soil is not consistent and the yield surplus per unit active ingredient is much lower in comparison with half-dose liming.

During the improvement of alluvial meadow, meadow and bog meadow soils which contain higher amounts of organic and inorganic colloids and have higher buffer capacity, it is still necessary and justified to incorporate the total amount of CaCO3 as calculated on the bases of soil analyses. In these soils, the expected full impact can only be reached if the full dose is used.

Based on the soil type and its organic and inorganic colloid content, a ranking can be set up which provides help in the application of lime. It is possible to get a comprehensive basis for determining the necessity of liming, as well as its order of importance and method by using the cartograms of genetic large-scale soil maps which contain the location and occurrence of soil types and physical soil forms, or, lacking these, the respective data of the nutrient examination registry of plot detail, or by comparing the local knowledge of the plot user and the soil analytical data showing the acidity and level of Ca supply of the soil/pH, y1, CaC03/. In addition to considering the level of soil acidity, liming has to be preferred mainly on soils which react to it more sensitively and those which have lower plasticity values and those that contain less humus.

Calculation of the amount of CaCO3 necessary for improvement:

- Skeletal and brown forest soils, raw and low humus content and low clay content alluvial soils:
  \[\text{CaCO}_3 \text{ need t/ha} = y_1 \times 0.005 \text{KA} \times 1.73\]

- Meadow, alluvial meadow and bog meadow soils:
  \[\text{CaCO}_3 \text{ need t/ha} = y_1 \times 0.01 \text{KA} \times 1.73\]

Based on the method introduced by MÉM NAK in 1979, the basis of calculation is the soil analysis of the ploughed layer. A multiplicator was introduced which depends on the Arany plasticity index obtained on the basis of the soil samples taken from the 0-30 cm profile (0.35-1.02).

Calculation of the amount of CaCO3 necessary for improvement:

\[\text{CaCO}_3 \text{ need t/ha} = y_1 \times \text{multiplicator}\]

If the plasticity index (KA) is above 30, half of the calculated improvement substance has to be applied on brown forest soils, except for pseudo gley and podzolic brown forest soils.

\[\text{CaCO}_3 \text{ need t/ha} = y_1 \times \text{multiplicator} / 2\]

If exchangeable acidity can be measured in the soil, it also has to be taken into consideration.

\[\text{CaCO}_3 \text{ need t/ha} = y_1 + y_2 \times \text{multiplicator}\]

### 3.4. 11. 3. 4. Substances used for the improvement of acidic soils

Limestone powder: limestone grist containing 95-98% CaCO3 which is produced from easily grindable limestones and truffaceous limestones.
Bog or lake lime: clean carbonic lime mined in peat-bogs, or lake lime of biogenic origin which gets solved in water and carbonic acid water more than limestone powder.

Beet potash: the by-product of sugar production, fine grained carbonic lime which contains organic material, phosphate and nitrogen that is favourable from the aspect of soil productivity.

Calcine: corrosive substance obtained during the grinding of the waste material of lime factories, containing CaO, Ca(OH)2 and CaCO3.

Industrial waste products: Ca-containing alkalinising substances which do not contain any pollutants.

3.5. 11. 3. 5. Implementation of meliorative liming

In the case of the conventional implementation of meliorative liming (i.e. if the liming substance is incorporated into the soil before sowing the crop to be produced), cultivation has two basic duties from the aspect of the efficiency of liming:

- providing the shallow and as balanced as possible mixture of liming substance into the soil,

- establishing a loose soil condition in the regularly cultivated upper layer which provides the downward movement of the liming substance mixed into the shallow soil, facilitated by water to an extent exceeding the need of crops.

The most important point is that tillage should only be done as deep as the upper layer of the soil which is the richest in humus, or, in the case of a thick humus layer, as deep as any layer which has unfavourable chemical and physical characteristics.

The proper technological order of applying the liming substance:

• Performing deep loosening if the soil moisture level is adequately low at the time of cultivation.
• Incorporating chemical substances (fertilisers, soil disinfectants) into the soil and the application of organic fertiliser onto the soil surface.
• Ploughing at a depth conforming to the local circumstances, but it should be as deep as possible on the given plot.
• Steady application of the liming substance onto the surface of the ploughed soil.
• Mixing the liming substance into the shallow soil (10-12 cm).
• Seedbed preparation, sowing

4. 11. 4. Improvement of sandy soils

In Hungary, the largest contiguous calcareous sandy soil is located in the Danube-Tisza mid-region, while acidic soil can be found in the Nyírség and Somogy area. It follows from the grain size of sandy soils that the proportion of rough pores is high and the water holding capacity is low. For this reason, there is an increased risk of drought and deflation. The amount of organic and mineral colloids is very low; therefore, their nutrient management is not adequate either. Due to the lack of any permanent plant cover, the extent of organic matter replenishment is low. The mechanical, chemical and biological improvement of sandy soils might be necessary.

Factors inhibiting yield on sandy soils:

• Solid formations (limestone concretions, iron pan, gypsum layer)
• Gley soil layer
• Highly carbonic lime content
• High sand content
• Strong acidification
• High salt content

4.1. 11. 4. 1. Mechanical improvement of sandy soils

1. Terrain correction: Evening out sand-hills and depressions. It is important that the fertile layer should be loaded back onto the surface eventually.

2. Water management: Helping precipitation and irrigation water seep into the soil, drainage of harmful surplus water.

3. Tillage: Deep tillage before planting standing cultures, incorporating fertilisers and meliorative substances.

4. Layered sand improvement: Putting a 2-3 cm thick contiguous fertiliser layer into 40-60 cm depth of the soil (Egerszegi's sand improvement). The aim is to reduce the speed of the downward movement of water, thereby improving water and nutrient supply. This is a rather costly process; therefore, it is only used in the case of intensive crop cultures.

5. Breaking up solid formations: loosening of the limestone concretions, iron pan and gypsum layer with deep tillage. Gley sandy soils are formed on low-lying areas which are frequently covered by water. The reductive circumstances can be decreased by loosening and aerating the soil.

4.2. 11. 4. 2. Other methods of improving sandy soils

The improvement of salty sandy soils can be carried out by removing the excess salt from the soil with irrigation and the establishment of a drainage network.

Improvement of calcareous sandy soils: Applying high colloid content and substances with low calcium content (farmyard manure, acidic bog, acidic meadow moor-peat, lignite powder). The vesicular character of the soil has to be terminated, thereby helping the extraction of organic matter.

The improvement of acidic sandy soils can be performed with lime containing substances. The calcareous moor-peat in the depressions of the Nyírség's sandy areas is suitable for improvement.

Biological improvement of sand: The improvement of soil conditions is done by specifically selecting crops for production. Production of nitrogen binding crops (melilot, etc.) on calcareous sandy soil, lupin on acidic sandy soil. Regular application of farmyard manure, deeply incorporated into the soil in order to improve the level of nutrient supply and the soil structure.

5. 11. 5. Improvement of the physical and biological soil condition

The aim of physical soil condition improvement: stopping excessive compactedness, inadequate water balance or dustification.

From the biological aspect, the soil condition is proper is the process of maturation is done. (maturation: favourable soil condition as a result of active soil life)

During soil use, the following factors are affected:

• porosity circumstances of the soil
• organic matter content
• micro- and macrobiological life
• moisture content
• temperature
11. Production site protection and improvement

- amount of organic and inorganic colloids

The improvement of the physical and biological soil conditions are served by modern soil protective tillage systems in a simultaneous and non-separable way.

Characteristics of the tillage directions preserving the physical soil conditions:

- reducing tillage
- reducing the number of operations and frequency of cultivation
- reducing the depth of tillage

Tillage methods preserving the physical condition of the soil:

- minimum tillage
- reduced tillage
- cost-saving tillage
- no-tillage
- conservation tillage

5.1. 11.5. 1. Reducing soil disturbance

- Reduced number of operations: reduces the extent of soil compaction caused by mechanical trapping
- Reducing the cultivation depth: the mechanical interventions of the soil can be reduced with shallow tillage or strip tillage.
- Omitting ploughing and primary tillage: the soil structure can be preserved by preferring loosening (Figure 71).

11.6. ábra - Figure 71. The impact of conventional and reduced tillage in the soil profile

(Conventional tillage -- Shallow tillage -- No tillage)

5.2. 11.5. 2. Development and maintenance of the loose soil layer close to the surface

The physical condition of the soil has to be modified in a way that it positively influences its biological condition.

The following options are available to modify the surface soil conditions:

1. Incorporating organic matter into the soil:
11. Production site protection and improvement

- incorporating legumes into the soil,
- farmyard manure,
- compost application.

2. Soil coverage

- crop residues,
- intermediate protective crop,
- farmyard manure,
- green manure.

3. Production of soil loosening crops.

Applying an organic cover layer (mulch) (Figure 71) after leaving crop residues on the field and forming a soil cover, it provides access for precipitation into the soil and prolongs the evaporation of soil moisture.

Mulch (an organic cover layer mixed with soil) has several favourable effects: preserving soil moisture, improving the structure of the surface soil layer, increasing biological activity and protecting the soil surface.

11.7. ábra - Figure 72. Applying mulch layer on the surface

During the production of soil loosening crops, the powerful growth of their roots has a loosening and dustification impact on the soil and their root residues increase the organic matter content of the soil. Examples of soil loosening crops are winter coleseed, oil radish, white mustard (Figure 73) and white melilot.

11.8. ábra - Figure 73. White mustard and oil radish
11. Production site protection and improvement
12. fejezet - 12. Land use systems

1. 12.1. The concept and basic elements of land use system

Land use system: it shows the location of land use classifications (ploughland, grassland, plantation, forest) in a given area, as well as their system of connections and relations to their environment. The land use system represents the area usage of sectors providing and serving agricultural production, as well as the connecting sectors. Land use depends on the actual employment of land, as well as the material and energy use. Soil use is the use of soil fertility for economic purposes. The rational use of soil is closely ulinked to its protection. During the production processes, soil quality has to be preserved and improved (structure, condition, fertility). The sustainable agricultural land use is a type of use which does not impose irreversible or negative impacts on the soil or other environmental factors. Of the aspects influencing land use on the plot level, it is important to emphasise the ecologic endowments, tillage-related impacts, as well as the ulinks with adjacent areas, surface and subsurface waters and the atmosphere.

Primarily, sustainable land use can be achieved with the practical methods of farming. These methods embrace a wide area from using tillage and nutrient management systems and melioration changes to crop protection interventions. A land use system is the collective of production technological, melioration and organisational procedures which characterise the intensity of soil use and the maintenance of soil productivity. Figure 74 shows the interconnection of the mentioned systems.

12.1. ábra - Figure 74. Subsystems in the land use system

![](image)

1.1. 12. 1. 1. The basis of distinguishing land use systems

It is possible to distinguish land use systems from each other on the basis of soil use, as well as the maintenance of soil productivity.

The method of soil use:

- soil use types
• crop rotation

Method of maintaining productivity:
• production technology
• melioration procedures

1.2. 12. 1. 2. Constituents of land use systems

In order to maintain the expected level of agricultural production, it is important to establish a scientifically grounded land use system that is able to make farming independent of the changing impacts of natural powers to the greatest possible extent. Neither economic production sectors comes close to agricultural production from the aspect of the wide range of aspects of ecologic factors that are needed to be taken into consideration. During the evaluation of the role of the listed general and supplementary constituents, one has to take the minimum law as a basis. Therefore, the first step is to stop or reduce the unfavourable impact of the factor that limits the effectiveness of the other factors, the maintenance or growth of soil productivity the most. Each element influences the maintenance and improvement of soil quality and yield stability depending on the actual circumstances. Where the yearly amount of precipitation is low, irrigation, forestation and the moisture loss reducing tillage cannot be omitted. If there is enough precipitation and the productivity of the given soil is low, fertilisation has increased significance. On acidic or alkaline soils, chemical improvement is necessary, while low-lying, water saturated soils are in need of water management.

General constituents
• the system of crop rotation
• tillage system
• fertilisation system
• soil protection system
• crop protection system
• sowing seed production system

Supplementary elements
• irrigation
• water management
• soil improvement
• forestation

The different land use systems can be distinguished on the basis of the listed general and supplementary elements.

2. 12. 2. Land use system types

The different land use systems were developed as a common result of population increase, the development of the production power of the society, industrial production, and scientific-technical advancement.

• uncultivated, pasture/forest switching
• fallow
• crop rotation
• ley
• free system
• monoculture and industry-like systems
• newer systems (biological, sustainable, adapting, value preserving, integrated)

2.1. 12. 2. 1. Uncultivated, pasture and forest switching tillage system

This ancient land use system used to be the agricultural practice from the ancient times to the feudalism. The most primitive form of land use. Low population density, nomad wandering lifestyle was dominant in this period. The forage need of animal husbandry was covered by the pastures. 10-20% of the area was used. The direct surroundings of the settlements are cultivated, cereals and vegetables are grown on the cultivated lands to cover people’s own needs. The productivity of the freshly broken soil was rather high in the first years, no actions were done in order to maintain or restore soil productivity. The cultivated area became poor in nutrients, the soil structure deteriorated and the land became infested with weeds. The primitive cultivation tools were not suitable for the maintenance of soil productivity, as time (4-6 years) passed, the soil productivity decreased, and the land was laid fallow after a few years of use. In the beginning, the uncultivated area was overgrown with weeds, then the regionally typical ancient vegetation gradually developed. Newer areas were included in production; therefore, there was enough area for cultivation in comparison with the population. Two development phases can be distinguished: ancient uncultivated and uncultivated land use.

Ancient uncultivated land use:
• Non-cultivated areas were broken and put into cultivation.
• The uncultivated areas were not broken again.
• 4-6 years of plough land use were followed by 50-60 years of uncultivated period.
• The uncultivated areas were put into cultivation again.

The change of crop composition in the fallow areas:
• weeds 1-4 years
• stolon crops 5-7 years
• thin canopy grasses 5-7 years
• thick canopy grasses 10-15 years
• needlegrass steppe stage >20 years

Forest switching land use system: In forest areas, natural forests were burned to gain land for field crop production. During burning, the soil was enriched in minerals. In 4-6 years, the soil became poor in minerals and the yield reduced significantly. The productivity of the soil significantly decreases in the ploughland period and the humic layer also deteriorates. After cultivation was discontinued, other forest areas were burned down. This tillage system is still used to this day.

Due to the loss of free areas and the extension of areas used in production, the duration of the uncultivated phase had to be reduced. Therefore, there were complete stages missing from the uncultivated period, especially the sections which were meant to facilitate the restoration of soil productivity. The soil that is low on nutrients is an aggravating circumstance. Since the continuously decreasing yield could not satisfy the needs of the increasing population, another system had to be developed.

2.2. 12. 2. 2. Fallowland use system

The fallow land use system was developed from the uncultivated land use system and it was dominant in agricultural production for more than 1000 years. It was known also in the slave-holder societies, but it appeared in Europe in the 7th century and it became generally used in the 10-11th century. The different land use methods
were established and field crop production became widely used. On the majority of ploughlands (50-80%), crop production was carried out; therefore, the proportions greatly changed in comparison with the uncultivated land use system. The whole ploughland area was cultivated in each year.

The restoration of land productivity was done by fallowing. The system is based on the use of natural nutrients. The 2-3 year long period of cereal production was followed by a 1-2 year long period without production.

The aim of soil resting:

- weed control,
- improving the structural condition of the soil,
- preserving the water stock of the soil,
- improving the extraction of nutrients.

Rotation farming:

- In the bipartial rotation system, the area was divided into two parts in the given year.
- In the tripartial rotation system, the area was divided into three parts.

Classification of commons:

There are differences between whole, partial, clean (black, or late) and occupied (green) fallows.

German classification:

- Whole fallow: the fallow phase lasts for one year
- Partial fallow: from the harvesting of cereals to the production of the catch crop

Russian classification:

- Clean fallow: either black or late fallow.
- Occupied fallow: production of short growing season green forage.

In the arid and semi-arid areas of the world, in places where irrigation is not possible, for water stock preservation purposes.

In the European Union member states:

- one of the tools of the regulatory mechanism of the agricultural market,
- state subsidisation,
- the culture condition of the fallow has to be maintained by applying partial fallow, black fallow and green fallow,
- it also serves the protection of the soil.

2.3. 12. 2. 3. Crop rotation land use system

It was developed from the fallow land use system. It was developed in the area of present day Belgium and The Netherlands in the 16th-17th centuries. It became general in England and France in the 18th century and in Germany in the 19th century.

In Hungary, it started to spread in the surrounding of cities and industrial establishments (sugar factory), as well as in farms dealing with intensive animal husbandry in the late 19th century.
There were significant changes in soil use. All production areas suitable for ploughland cultivation were broken; therefore, the production of forage crops was switched to ploughlands. Such crop production systems were developed in farms where more intensive animal husbandry was carried out. These systems mostly worked in the Transdanubian region, where the proportion of fodder crops produced on plough lands was higher. After the discovery of new continents, several important crop species were transported to Europe. As a result of the improving domestication and breeding techniques, new varieties of increasing productivity were produced. The crop rotation land use system can be characterised by variable crop composition and order. The one-sided cereal production was gradually ceased to be used, people switched to developed animal husbandry and the production of several types of crops. The development of animal husbandry necessitated the production of perennials and annual rough fodder crops, as well as root crops. In addition to fodder crops, an increasing proportion of industrial crops were produced. Fallowing ceased to be used and farmers strived no to have any unsown ploughland. Crop production based on crop rotation was developed. Crops produced on ploughlands can be classified into two groups: crops which exhaust and those which enrich soil productivity. They introduced a crop order in which two groups of crops changed each other from year to year in the same area. No crops exhausting soil productivity were produced in succession. The crop rotation land use system was better than the fallow land use system in that it used the soil in a multiform way.

Further characteristics:

• Legumes which took over the place of the fallow phase play important role in maintaining soil productivity.

• The developing animal husbandry made it possible to use farmyard manure.

• The use of fertilisers started in the second half of the 19th century.

• Mechanisation started to developed: steam-ploughs, tractors, mechanisation of harvesting, thresher.

• The achievements of maintaining and improving soil productivity, the development of fertiliser and machinery production and the use of crop protection and selection show the advancement of agricultural and its related sciences. As a result of the versatile development, yields also increased.

2.4. 12. 2. 4. Development of the Norfolk crop rotation system

The four-section Norfolk crop rotation (1st winter wheat, 2nd root crops, 3rd winter barley with red clover undersowing, 4th red clover) was widespread in England and then other European countries, too. In this system, the proportion of crops typical of the crop rotation system is expressed: cereals 50%, root crops 25%, fodder crops 25%. Similar crop composition and order could be developed under circumstances where the yearly precipitation was sufficient and the vegetation period was long enough to prepare the soil for winter wheat after the red clover which was sown on the fallow. In England, farmers conformed to the proportion, while in Germany and Austria; the crop rotation system did not limit the production of cereals that strictly. In other countries, farmers did not even always conform to yearly crop rotation. In more advanced animal husbandry farms, red clovers and other legumes were produced for two years for foraging (e.g. wild pea mix) or seed production purposes (bean, pea).

2.5. 12.2.5 Ley land use system

Basic principle:

• The soil structure of steppe chernozem deteriorated by several years of plough-land soil use can be restored by the simultaneous sowing of grass and legumes.

• The plough-land is used with annual crops and grasses are produced for several years for foraging purposes.

• The duration of the long soil regeneration typical of the fallow period can be shortened with the simultaneous sowing of grasses and perennial legumes.

• The advantages of the grass-clover system were not reinforced by experiments performed in other countries.

2.6. 12.2.6 Free land use system
It became widespread in Hungary in the period after the First World War. It was developed from the crop rotation system. This system was developed from the crop rotation tillage system, mostly in lease farms. The lessee who was well provided with capital leased a several hundred or even thousand acre farm for a previously set yearly price. As they wanted to reach the largest possible profit in a short period of time, they developed their farming and land use system accordingly.

Characteristics:

The crop composition changed from year to year without any plans, the impact of the previous crop was neglected. The proportion and composition of forage crops changed from year to year depending on the need of animal husbandry. The composition and proportion of cash crops were adjusted to the market needs, the risk of which could only be properly managed by companies that are well provided with capital. No crop rotation was used. Between the two world wars, the agricultural machinery developed significantly in Hungary and in Europe. The use of better machinery was shown tillage quality. Deeper tillage and mechanical harvesting became more widespread. The maintenance of soil productivity was done with farmyard manure and fertiliser.

2.7. 12.2.7. Monoculture land use system

The extreme form of the concentration and specialisation of production.

Crops produced in monoculture:

- Wheat, maize and cotton in the USA,
- Rice in China,
- Sugar cane in Egypt and Cuba.

Characteristics:

It could represent either a high or low rate production (extensive and intensive). As regards soil use, this system is one-sided as it produces interrupting crops from time to time in certain parts of the area or on given plots. This practice could have two different causes: the need for thinning of the propagated weeds and pests or the production of other products. In order to improve the soil life which became one-sided as a result of monoculture, green manure crops are produced. In intensive systems, soil productivity is maintained with fertilisation. In more backward systems, nutrient supply is done with farmyard manure application. In the case of producing crops with wide row spacing, soil protection is especially important, e.g. in the case of open furrow cultivation. One-sided crop production is beneficial for the propagation of pathogens, pests and weeds. High-level crop protection is needed in order to limit these factors. Monoculture production cannot be implemented without high-level chemical weed control. As the period of crop production without rotation increases, diseases, insects and weeds become more frequent. In severe cases, chemical and integrated protection are not effective enough and the production of the given monoculture crop has to be stopped. In modern large farms, it is an objective to mechanise the whole chain of production procedures and they use few, but modern tools. The cost of mechanisation is lower; therefore, the profit can be higher. In many cases, the given climate is the most favourable for a certain crop, e.g. the northern part of the USA is the most favourable for wheat, the central part is the best for maize and the southern part is the most beneficial for cotton. It is an advantage of monoculture production that the soil can be adjusted to the characteristics of the produced crop. In this system, the farmer becomes an expert of the given crops, but this work still does not mean occupation for the whole year.

2.8. 12.2.8. Current land use systems

As a result of the social and economic changes triggering the development of land use systems, as well as the development of science and technology, lands can be used in various types of systems. The currently used land use systems can be distinguished based on their efficiency and their relations with the environment. The efficiency of the land use system means the mass and quality of product produced in an area unit based on the inputs used. Efficiency is not necessarily in connection with the stage of development. The relation of the land use system with the environment is characterised by the extent of its dependence on the environment and natural resources, as well as the extent and nature of their impact on the environment.

Recently developed land use systems and those still under development:
12. Land use systems

- Industry-like production systems
- Alternative (ecological) farming systems
- Integrated crop production systems

Industry-like production can be characterised by the gradual substitution and extensive supplementation of natural resources by artificial resources, as well as the strive to increasing yields. The increasing production results in deteriorating environmental conditions (soil acidification, contamination of living waters, chemical residues etc.). For this reason, initiatives which submit crop production to ecological and environmental protection aspects are becoming increasingly widespread. There is increasing interest in applying farming and methods (integrated, alternative, rational, etc.) whose impact on the soil and the environment is much gentler than that of previous systems. Compared to the production systems described so far, these systems represent a complex activity, as they embrace the agricultural production chain partially or as a whole.

In industry-like production systems, farmers try to achieve high yields by making use of resources and the regulated agro technical procedures effectively. They use sowing seed of high biological value, large amounts of fertilisers and pesticides in production. They produce crops in accordance with previously developed technological procedures, utilising cutting-edge scientific findings. The accurate and efficient implementation of technological processes is performed with power machinery. The agrotechnical elements are under continuous development by means of the collection of production observations and economic data. In the early times, this system was only used in the industry-like production of a given crop (maize, potato, wheat, soybean). Nevertheless, building only on one crop did not align with the farm profiles which took a long time to be completely developed. Although specialisation was also started in crop production, the majority of the systems undertake the modernisation of several partial areas. In industry-like systems, production costs are significant, while the increase of material and energy prices reduces profitability and makes the standard of production variable. The regular use of chemical substances leads to the possibility of environmental damages (soil acidification, accumulation of chemical residues, contamination of water bases, damaging of habitats, etc.). In addition, food quality might also deteriorate. Intensive production could result in the deterioration of the soil condition (dustification, compaction, organic matter loss, soil life deterioration, etc.). The listed aspects also show the environmental risk of industry-like production.

Expectations aimed at reduced environmental load and healthier foods necessitated the development of new land use systems. In the 1980s, efforts towards switching to human- and environment-centered farming became more popular both in the scientific life and in practice. These ideas were manifested in the concept of alternative and integrated crop production.

Instead of making maximum use of the ecological potential, alternative (ecological) farming systems aim to reach the ecological maximum of yield and they do not consider any economic advantage. These systems consider it to be rational to use adapting environmental and regional management, to use biological bases in accordance with the given region and to perform preserving cultivation that is in accordance with the given soil type. They are based on the weed control role of crops and the productivity maintenance and ecologically balancing role of the soil in multi-section crop rotations. The use of chemicals is substituted by crop rotation, the wide range of varieties, sowing date, tillage, mechanical weed control and the different agrotechnical tools. Also, only natural substances are used as pesticides. Instead of artificial N fertilisers, organic fertilisers and the sparingly soluble forms of phosphorus and potassium are used to maintain the soil’s production capacity. The main N source is the production of N binding crops in the crop rotation. As a result, the extent of NO3 leaching and the losses of the gas form of ammonia decrease.

Soil productivity is maintained by means of the increasing amount of biomass. The results can be shown in the richness of the flora and fauna, the biotope protection, the reduction of chemical residues and the quality of foods. As a result of omitting synthetic pesticides, the risk of the yield getting contaminated with the toxins produced by pathogens is higher. For this reason, alternative farming, but especially ecological farming calls for proper care and expertise. The related regulations have a determinant role in the spreading of ecological farming. Proper indication on the given products and regular inspections are important parts of the regulation.

The integrated production systems undertake the establishment, improvement, or maintenance of the harmony between crop needs, production site endowments and economic circumstances. They unite the favourable objectives and tools of industry-like and alternative systems within one system. By means of rational compromises, these integrated production systems enforce environmental protection aspects the same way as the
new findings of scientific-technical development. In other words, products are produced with an ecological approach by using the minimally needed amount of chemicals while still being profitable.

In integrated crop production, it is an especially important task to achieve and maintain profitability in production at the lowest possible extent of environmental damage.

The integrated approach embraces the whole system of soil use. Fertilisation is many-sided, the available farmyard manure is used up and any further need is covered by artificial fertilisers. Crop residues are used as the sources of organic matter replenishment. Green manuring and the inclusion of green manure crops into the crop rotation are becoming increasingly important. The system of fertilisation, tillage and crop rotation form a harmonious system with each other. In this system, the humus balance and moisture management are of utmost importance. The aim of tillage is the mitigation of unfavourable soil conditions and the increase of the efficiency of production technological interventions. In order to reduce the environmental load, only the absolutely necessary doses of artificial fertilisers and chemical pesticides are used. In order to reduce chemical use, soil analysis results, forecasts, preventive protection and integrated crop protection solutions such as the production of resistant varieties and crop rotation are used. In integrated systems, the objective is to achieve an economically optimal yield level. The quality and safety level of the produced products is good, the quantity of chemicals or contaminations of biological origin is minimal or not traceable. By unifying the ecological and economic aspects, the concept of sustainable agricultural production can be enforced in integrated systems the most.

In land use, one must strive to develop a system which is able to make the success of farming independent of the often unfavourable impacts of natural forces the most. A land use system cannot be developed in accordance with a scheme that refers to a whole country. Any system or trend is more advanced than the previous ones if it takes over the good aspects from the previous ones, it notably furthers farming by means of its novelty, it eases work, preserves nature, makes it possible to achieve a better quality and it can be implemented on a realistic cost level.
13. fejezet - 13. Irrigation farming

1. 13.1 The impact of irrigation on the soil

During irrigation farming, the soil is exposed to more intense mechanical loading that is caused by the structural degradation resulting from the impact of the irrigation water reaching the surface and the compaction damage on wet soil. During irrigation farming, soil loading accompanied by the continuous moistening of soil has to be taken care of. Research finding and observation shows that it is not the irrigation itself which damages the soil, but the irrigation method, intensity and amount of water which neglect soil characteristics. In addition to performing irrigation, the proper water uptake and aeration of the usually is usually neglected. The frequent moistening caused by irrigation poses a threat of both excessive anaerobiosis and the mechanical damaging of the soil structure. The regularly cultivated layer of irrigated soils is recompacted quicker and to a greater extent. Soil compaction greatly deteriorates the water management characteristics of the soil: its water conduction ability, and the amount of water that is stored in the soil and accessible for plants. The plough-pan layer which is developed under the regularly cultivated layer affects the water balance of the whole soil profile. The looseness of the soil basically determines the effectiveness of the applied irrigation water. The compacted layer blocks the complete infiltration of precipitation and irrigation water into the soil (Figure 74). If the intensity of the applied irrigation water exceeds the extent of the water conduction ability of the soil, the irrigation water is stuck on the surface and in the layers close to the surface and the majority will be evaporated and wasted.

13.1. ábra - Figure 74/b. Deterioration of the soil surface as a result of irrigation

In order to provide the quick and steady movement of the water entering the soil within the soil profile, the following have to be considered:

• The irrigation intensity is usually higher than the water uptake of the soil and the layer soaked with irrigation is saturated with moisture until its maximum water-holding capacity.

• As a result of the maximum or nearly the maximum moisture saturation, the air content of the porosity of the soil is reduced to the minimum.

• The unfavourable physiological effect caused by the insufficient air supply of the plant root can be further increased by the cold irrigation water.

• The adverse condition arising from the high moisture saturation lasts until the water-air proportion of the soil reaches the 70:30 ratio needed by plants.

• If the water permeability of the soil is good (100-300 mm/h) or especially good (300 mm/ha), one can expect the shortening of the airless period of soil during irrigation.

• If the water permeability of the soil is average (70-100 mm/h), weak (<30-70 mm/h), or, especially if it is very weak (>30 mm/h), inadequate air supply of the soil will follow (Figure 75).

13.2. ábra - Figure 75. Impact of irrigation on the moisture cycle of the soil
2. 13.2 Tillage of irrigated soils

The probability of the silting processes going on in the uppermost layer of the soil has to be considered during cultivation. The duty of tillage is to make possible to enable the water reaching the soil surface to enter the soil with the proper intensity, quick and steady movement of the water entering the soil within the soil profile and the air supply of the soil and the plant roots.

Under irrigated circumstances, the following aspects have to be considered during the planning of cultivation:

- The water infiltration of the soil has to be improved with tillage methods that protract the silting and surface closure effect of the water reaching the surface.
- The use of tools causing soil dustification has to be avoided.
- Circumstances leading to compaction, i.e., the cultivation of wet soil have to be avoided.
- The soil layer which is usually deteriorated in the upper structure of the soil has to be ploughed under the surface.
- In accordance with the crop order, primary tillage procedures have to be applied for the purpose of soil condition improvement and water loss reduction which spares the soil structure.
- Proper looseness has to be established or preserved until the depth of the root zone, the structure of the upper layer has to be preserved outside the growing season (coverage, sowing green manure crops) (Figure 76).
- Irrigation reduces the cultivation effect by means of the faster deposition of soil; therefore, the condition of the root zone has to be verified more often and improved if needed.
- The soil between rows has to be loosened following the irrigation of crops that are especially sensitive to the air supply of the soil and the closure of the soil surface.
- During the vegetation period, the improvement of the looseness and porosity of the soil which has become increasingly compacted as a result of irrigation.
13. Irrigation farming

13.3. ábra - Figure 76. Plant residue cover to protect of the soil surface of irrigated soils

On irrigated soils, the cultivation procedures have to be performed with the consideration of the change soil moisture conditions.

During the stubble stripping and treatment, increased attention must be paid to the reduction of soil moisture loss. The soil moisture loss can be reduced with the closure of the soil surface and the partial coverage of the stripped surface. Structure preserving solutions have to be preferred, i.e., the stripping performed with cultivator to disc cultivation. Due to the wet soil condition, weed and volunteer plant emergence has to be expected under irrigated circumstances; therefore, the mechanical treatment cannot be neglected.

Under irrigated circumstances, there will be a larger stem mass after harvesting. In the case of harvesting the crop residues which leave behind large amounts of stem, crushing and milling are needed.

On irrigated soils, the cultivator procedure can be used as primary tillage, providing the advantage of preserving the soil structure. After early harvested previous crops, the primary tillage of late summer- or autumn-sown plants is recommended to be done with a cultivator or a flat disc dustifier.

If the layer to be loosened becomes dry, moderately deep loosening can be used for soil condition improvement purposes after early harvested previous crop in the case of spring-sown plants. The surface of the opened soil has to be levelled and closed. If soil conditions are wet and especially in the case of late harvested previous crops, primary tillage is recommended to be performed with a plough. The upper layer that usually has a deteriorated structure should be ploughed back under the surface. Plough pan soil compaction could be avoided if the depth of ploughing is different than that of the preceding year. Ploughing should be carried out if the soil surface can be finished in one operation with a tool mounted on or after the plough.

As a result of regular irrigation, the soil whose structure is damaged becomes more sensitive to physical loading. The silting of the soil surface, as well as the faster depositing and recompaction of the cultivated layer are frequent phenomena. In the case of soils with average or weak water infiltration capacity deep cultivation is needed to increase the irrigation efficiency. The necessary depth of cultivation is determined by the depth of adversely compacted layers and the thickness of the layer expected to be soaked with irrigation. During the planning of deep loosening, one has to expect that irrigation reduces the duration of impact of deep loosening by around 1-2 years.

In the case of late summer- and autumn-sown plants and before the sowing of spring cereals, seedbed preparation and sowing can be performed in one operation with less compaction damage, clods and dust fraction.

During the spring tillage of root crops, multi-operation soil preparation methods should be avoided. The use of tools smearing, kneading and dustifying the soil (e.g. traditional disc, smoother) should be avoided. After sowing, profiled surface has to be developed also in order to avoid silting.
Under irrigated circumstances, it is important to perform interventions that improve the condition of the soil surface during the growing season. Silting (disintegration of aggregates), crustation and cracking can occur in regularly irrigated areas, depending on the water resistance of the structural elements constituting the soil. The treatment procedures of irrigated plants aim at the improvement of the surface conditions of the regularly soaked soil and at weed control. The cracked and crusty character in the emerging population of plants at their initial development stage can be loosened with spoked hoe. The aim of the row spacing cultivation of root crops is the dustification and aeration of the upper layer which is deposited as a result of water, the control of emerging weeds and the occasional incorporation of fertilisers into the soil. Following irrigation, row spacing cultivation can be performed after the drying of the soil.
14. fejezet - 14. The natural regions of Hungary

1. 14.1 List of Hungary’s natural regions

Danube plain
- Danube flatland
- Danube-Tisza mid-region flatland
- Bácska ridge
- Mezőföld
- Dráva flatland

Tisza plain
- Upper Tisza region
- Central Tisza region
- Lower Tisza region
- North Great Plain alluvial cone flatland
- Nyírség
- Hajdúság
- Berettyő-Körös region
- Körös-Maros mid-region

Little Plain
- Győr basin
- Marcal basin
- Komárom-Esztergom flatland

Western Hungarian periphery region
- Feet of the Alps
- Sopron-Vas flatland
- Kemenes Ridge
- Zala hills

Transdanubian hill country
- Balaton basin
- Outer Somogy
- Inner Somogy
• Mecsek and Tolna-Baranya hill country

Transdanubian Mid-Mountains

• Bakony region

• Vértes-Velence highlands

• Dunazug highlands

Northern Hungary Mid-Mountains

• Visegrád mountains

• Börzsöny

• Cserhát region

• Mátra region

• Bükk region

• Aggtelek-Rudabánya highlands

• Tokaj-Zemplén highlands

• North Hungarian basins

The region and crop production constitute a close unity. The proportion of ploughlands is between 50-80% in the regions of the Great Plain and the Little Plain, while that of highlands and hilly areas is below this value. Factors affecting cultivation type and the crop structure include soil characteristics (i.e. the developed soil type, slope of the area), hydrological factors, climatic circumstance. This section aims to provide a brief description of each regional unit.

2. 14.2. Danube plain

• Danube flatland

• Danube-Tisza mid-region flatland

• Bácska ridge

• Mezőföld

• Dráva flatland

2.1. 14.2.1 Description of the Danube flatland

• Soil types: Mid-heavy alluvial soils, skeletal soils, chernozem soils, meadow soils.

• Yearly mean precipitation sum: 540-670 mm

• Number of sunny hours from April to October: 1440-1490

• Total heat sum: 3000 °C-3200°C

• The establishment of floodplain forests, grasslands and pastures is substantiated in areas where raw alluvial and meadow soils prevail. In areas suitable for field crop production, mainly chalk preferring and chalk tolerant crops are produced with success.

• Typical produced crops: winter wheat, winter barley, maize, sugar beet, sugar beet, hemp, soy, pea, alfalfa, seasoning paprika, green paprika, cabbage, melilot, as well as radish, seasoning and green paprika in seed production
2.2. 14.2.2 Description of the Danube-Tisza mid-region flatland

- The largest contiguous sandy area of Hungary.
- Yearly mean precipitation sum: 500-550 mm
- Number of sunny hours from April to October: 1450-1500 hours
- Total heat sum 3050-3250 °C
- Typical produced crops: fruits: apple, apricot, peach, pear, sour cherry, cherry, grape, vegetables: tomato, gherkin, green pea, melon, seasoning paprika, field crops: winter wheat, rye, sorghum, millet, sunflower, potato, tobacco, alfalfa, melilot.

2.3. 14.2.3 Description of the Bácska ridge

- Soil types: chalcareous chernozem soils
- Yearly mean precipitation sum: 580-620 mm
- Number of sunny hours: 1480-1500
- Total heat sum: 3200 °C-3250°C
- Typical produced crops: usually, every kind of crops can be produced on chernozem soils, but the main produced crops include winter wheat, winter barley, maize, sugar beetsugar beet, sunflower, rape, pea, alfalfa, fibre hemp and soy which prefer heat. Grape and fruit production is usual in this region.

2.4. 14.2.4 Description of the Mezőföld

- Soil types: the most dominant soils are calcareous chernozem soils, while alkaline, meadow, bog meadow and bog soils are also frequent in areas with higher groundwater levels.
- Yearly mean precipitation sum: 500-600 mm
- Number of sunny hours: 1440-1470
- Total heat sum: 3050-3150°C
- Typical produced crops: winter wheat, winter barley, potato, maize, sugar beetsugar beet, fibre hemp, alfalfa, pea, soy (in the southern part of the region) and tobacco. Grape and fruit production prevails in the more sandy areas. Under irrigated conditions, vegetable production could be successful on humic sandy soils, but garden seeds are also produced in these areas.

2.5. 14.2.5 Description of the Dráva flatland

- Soil types: alluvial meadow, bog meadow and meadow chernozem soils in low-lying floodplains, chernozem soils and brown forest soil in higher areas.
- Yearly mean precipitation sum: 650-750 mm
- Number of sunny hours: 1360-1480
- Total heat sum: 3050-3200°C
- Typical produced crops: winter wheat, winter barley, oat, maize, sugar beetsugar beet, potato, fibre flax, alfalfa, red clover. The most typical vegetables are green paprika and radish.

3. 14.3 Tisza Plain

- Upper Tisza region
• Central Tisza region
• Lower Tisza region
• North Great Plain alluvial cone flatland
• Nyírség
• Hajdúság
• Berettyő-Körös region
• Körös-Maros mid-region

3.1. 14.3.1 Description of the Upper Tisza region

• Soil types: meadow, alluvial meadow, raw alluvial and bog soils, which call for very careful and circumspect cultivation. The quality of cultivation basically determines the achievable yield. Due to their high moisture content and less favourable water management, these soils are cold; therefore, farmers have to wait in the spring before sowing, so that they get warm enough.

• Yearly mean precipitation sum: 600-650 mm
• Number of sunny hours: 1380-1400
• Total heat sum: 2900-3000°C

• Typical produced crops: winter wheat, winter barley, rye, winter barley, oat, sunflower, oil flax, fibre flax, seed-produced hemp, vetch species, pea, red clover. Potato and sugar beet are also produced to a lesser extent. Previously, floodplain orchard were typical of this region, currently produced fruits include walnut, plum, sour cherry and apple.

3.2. 14.3.2 Description of the Central Tisza region

• Soil types: meadow, alluvial-meadow soils. The current outlook of the region was formed by the river regularisation procedures. Alkaline soils are present in a huge area, these are used as pasture. Great Plain chalcareous chernozem and meadow chernozem soils are present in a low proportion, but these are the most productive soils in the area.

• Yearly mean precipitation sum: 510-560 mm
• Number of sunny hours: 1450-1500
• Total heat sum: 3100-3200°C

• This region is the driest area in Hungary, it is struck by drought the most.

• Alkaline soils have a large proportion, these are used as pastures. Nature conservation areas and fish-ponds can be found in the Hortobágy region.

• Produced crops: winter wheat, winter barley, maize, sugar beet, sunflower, pea, alfalfa, hemp, poppy, sorghum, grass pea.

3.3. 14.3.3 Description of the Lower Tisza region

• Soil types: meadow and alluvial meadow soils, as well as chernozem soils in a low proportion

• Yearly mean precipitation sum: 540-560 mm
• Number of sunny hours: 1500-1520 (the highest in Hungary)
• Total heat sum: 3250-3300°C (the highest in Hungary)
• Produced crops: crops which have high heat and sunlight need, winter wheat, winter barley, maize, sugar beetsugar beet, sunflower, ricinus, pea, alfalfa, fibre hemp, broomcorn, seasoning paprika, onion.

3.4. 14.3.4 Description of the North Great Plain alluvial cone flatland

• Soil types: meadow, solognac meadow and meadow chernozem soils, chernozem brown forest soils.
• Yearly mean precipitation sum: 550-570 mm
• Number of sunny hours: 1420-1470
• Total heat sum: 3050-3150°C
• Produced crops: winter wheat, maize, sugar beetsugar beet, pea, tobacco, potato, hemp, alfalfa, sunflower, silo maize, winter barley, canary grass. Melon production is carried out in the area of Heves, while grape and fruit production is more usual on slopes of southern exposure.

3.5. 14.3.5 Description of Nyírség

• Soil types: 'Kovárvány' brown forest soil, meadow, bog meadow and meadow bog soils.
• Yearly mean precipitation sum: 560-610 mm
• Number of sunny hours: 1400-1450
• Total heat sum: 2950-3100°C
• Produced crops: rye, potato, sunflower, lupin and hairy vetch are recommended for production on acidic sandy soils with low humus content. In addition to the above mentioned crops, mainly winter wheat, winter barley, tobacco, pea and vetch species are produced on sandy soils with high humus content and good structure. Horseradish has great tradition in areas where meadow-like soils prevail. Apple plantations are also significant in the region.

3.6. 14.3.6 Description of Hajdúság

• Soil types: typical flat agricultural region with chernozem soils of outstanding productivity.
• Yearly mean precipitation sum: 550-570 mm
• Number of sunny hours: 1420-1470
• Total heat sum: 3050-3150°C
• Produced crops: winter wheat, maize, sunflower, sugar beetsugar beet, alfalfa, potato, vetch species, bean, pea, hemp, tobacco.

3.7. 14.3.7 Description of the Berettyó-Körös region

• Soil types: alluvial soils, meadow, solognac meadow, meadow chernozem soils. This area is the most low-lying regional unit of the Great Plain. Due to the groundwater level close to the surface (1-2 m) and the high swelling clay mineral content, there is an increased risk of drainage water in the area.
• Yearly mean precipitation sum: 550-570 mm
• Number of sunny hours: 1440-1460
• Total heat sum: 3150-3200°C
• Produced crops: winter wheat, winter barley, oat, maize, sunflower, hairy vetch, canary grass. Winter wheat, maize, sugar beetsugar beet, pea, vetch species, alfalfa and hemp provide high yields in the chernozem-like
soil. Certain parts of soils with high plasticity are also suitable for rice production. Winter wheat, winter barley, red clover, alfalfa and sunflower are produced as the change crop of rice.

### 3.8. 14.3.8. Description of the Körös-Maros mid-region

- Soil types: meadow chernozem, chalcareous chernozem, deeply salty meadow chernozem.
- Yearly mean precipitation sum: 530-570 mm
- Number of sunny hours: 1450-1500
- Total heat sum: 3200-3250°C
- Produced crops: winter wheat, winter barley, red clover, alfalfa, broomcorn, sorghum produced for seeds, ricinus. The onion produced in the area of Makó is famous.

### 4. 14.4 Little Plain

- Győr basin
- Marcal basin
- Komárom-Esztergom flatland

#### 4.1. 14.4.1 Description of the Győr basin

- Soil types: alluvial, alluvial meadow, meadow, bog meadow soil, chernozem. The favourable crop production endowments and the relatively high yield safety of the relatively dry Little Plain are mainly due to the supplementary precipitation coming from the groundwater in a capillary way.
- Yearly mean precipitation sum: 590-690 mm
- Number of sunny hours: 1360-1410
- Total heat sum: 2850-3000°C
- Typical produced crops: winter wheat, winter barley, spring barley, maize, peas, soy, sunflower, sugar beets, fodder beet, chicory, fibre flax, fibre hemp, alfalfa, red clover, crimson clover, short growing season soy, lentil, buckwheat, vegetables: green paprika, cabbage species, onion, tomato.

#### 4.2. 14.4.2 Description of the Marcal basin

- Soil types: brown forest soil, chernozem, bog meadow soil.
- Yearly mean precipitation sum: 600-650 mm
- Number of sunny hours: 1390-1410
- Total heat sum: 2950-3050°C
- Produced crops: winter wheat, autumn and spring barley, oat, pea, winter coleseed and red clover.

#### 4.3. 14.4.3 Description of the Komárom-Esztergom flatland

- Soil types: skeletal soils, humic sand, sand drift, meadow alluvial soil, chernozem.
- Yearly mean precipitation sum: 570-600 mm
- Number of sunny hours: 1400-1410
- Total heat sum: 2950-3050°C
• Produced crops: winter wheat, autumn and spring barley, maize, winter coleseed, sunflower, sugar beet, alfalfa, red clover. Potato, fibre flax, fodder beet and cockshead are also produced to a lesser extent.

5. 14.5 Western Hungarian periphery region

• Feet of the Alps
• Sopron-Vas flatland
• Kemenes Ridge
• Zala hills

5.1. 14.5.1 Description of the Feet of the Alps

• Soil types: brown forest soil, leached brown forest soil, meadow alluvial soil
• Yearly mean precipitation sum: 700-800 mm
• Number of sunny hours: 1280-1340
• Total heat sum: 2800-2850°C, the coldest and wettest region of Hungary.

• Typical produced crops: forest use is the most usual, the proportion of fruit production is lower. Grape plantations are also frequent in the Sopron mountains. Sweet chestnut plantations and garden tree nurseries are typical in the Köszeg mountains. In areas where crop production is possible, the following crops are produced: winter wheat, spring barley, oat, rape, fibre flax, red clover, alfalfa, crimson clover, sugar beet.

5.2. 14.5.2 Description of the Sopron-Vas flatland

• Soil types: brown forest soil, chernozem brown forest soil.
• Yearly mean precipitation sum: 700-800 mm
• Number of sunny hours: 1300-1400
• Total heat sum: 2850-3000°C

• Typical produced crops: winter wheat, spring barley, oat, rape, fibre flax, red clover, alfalfa, crimson clover, sugar beet

5.3. 14.5.3 Description of the Kemenes Ridge

• Soil types: brown forest soil, brown forest soil with clay illuviation, alluvial soil
• Yearly mean precipitation sum: 700-800 mm
• Number of sunny hours: 1300-1400
• Total heat sum: 2850-3000°C

• Typical produced crops: The region is mostly suitable for forest use and grass production. In areas where soils have higher productivity, the following crops are produced: winter wheat, spring barley, peat, winter coleseed, red clover, crimson clover and white clover.

5.4. 14.5.4. Description of the Zala hills

• Soil types: pseudo-gley brown forest soil, brown forest soil with clay illuviation, meadow and alluvial soils.
• Yearly mean precipitation sum: 700-800 mm
• Number of sunny hours: 1300-1400

• Total heat sum: 2850-3000°C

• Typical produced crops: winter wheat, winter barley, rye, rape, oat, sugar beet, winter coleseed, fibre flax, alfalfa, red clover, crimson clover, white clover.

6. 14.6 Transdanubian hill country

• Outer Somogy

• Inner Somogy

• Tolna-Baranya hill country

• Mecsek and Mórágy hills

6.1. 14.6.1 Description of Outer Somogy

• Soil types: brown forest soil with clay illuviation, meadow, bog meadow soil chalcareous chernozem.

• Yearly mean precipitation sum: 600-700 mm

• Number of sunny hours: 1430-1450

• Total heat sum: 3050-3100°C

• Typical produced crops: winter wheat, spring barley, winter barley, maize, sugar beet, sunflower, pea, fibre flax. The speciality of the region is vegetable sowing seed production: carrot, table beet, garden sorrel, kohlrabi, radish, salad, gherkin, bean and various pea varieties.

6.2. 14.6.2 Description of Inner Somogy

• Soil types: brown forest soil with clay illuviation, rusty brown forest soil, meadow alluvial and bog soil.

• Yearly mean precipitation sum: 700-800 mm

• Number of sunny hours: 1340-1420

• Total heat sum: 3000-3050°C

• Typical produced crops: winter wheat, rye, winter barley, maize, potato, sunflower, winter coleseed, tobacco, pea, lupin, fodder beet, oil flax, buckwheat, red clover, white clover, crimson clover. The region is suitable for vegetable production.

6.3. 14.6.3 Description of the Tolna-Baranya hill country

• Soil types: brown forest soil with clay illuviation, chernozem brown forest soil, meadow and meadow alluvial soils.

• Yearly mean precipitation sum: 680-720 mm

• Number of sunny hours: 1400-1450

• Total heat sum: 3000-3150°C

• Typical produced crops: Grape production is very important in the agricultural use of the region. Produced field crops: winter wheat, winter barley, spring barley, oat, sunflower, sugar beet, winter coleseed, potato, fibre flax, pea, soy, alfalfa, red clover. The region is suitable for the sowing seed production of vegetables. Fruit production is also significant: in addition to apricot, peach and plum plantations, the sweet chestnut plantations are good examples of the Mediterranean climatic impact.
6.4. 14.6.4 Description of the Mecsek and Mórágy hills

- Soil types: brown forest soil, chernozem brown forest soil.
- Yearly mean precipitation sum: 680-720 mm
- Number of sunny hours: 1400-1450
- Total heat sum: 3000-3150°C
- Typical produced crops: 80% of the region is covered by forests and the rest is used as grape and sweet chestnut plantations. Furthermore, the following field crops are produced in the areas suitable for ploughland use: winter wheat, winter barley, spring barley, maize, sunflower, potato, alfalfa and ricinus.

7. 14.7 Transdanubian Mid-Mountains

- Bakony region
- Vértes-Velence highlands and its region
- Dunazug highlands

7.1. 14.7.1 Description of the Bakony region

- Soil types: Brown forest soil, brown forest soil with clay illuviation
- Yearly mean precipitation sum: 650-750 mm
- Number of sunny hours: 1350-1400
- Total heat sum: 2700-2950°C
- Typical produced crops: mainly forest use and grape to a lesser extent. Crop production can be successfully performed only in the basins: Rye, oat, spring barley winter wheat, winter coleseed, potato, pea. Previously, ergot used to be the real speciality of the region.

7.2. 14.7.2 Description of the Vértes-Velence highlands and its region

- Soil types: brown forest soil, chalcareous chernozem, meadow, meadow alluvial soils.
- Yearly mean precipitation sum: 570-670 mm
- Number of sunny hours: 1380-1400
- Total heat sum: 2800-2950°C
- Typical produced crops: significant forest and grape use, while ploughlands are also significant in the basins. Produced crops include winter wheat, winter coleseed, alfalfa, maize, sunflower, pea, oat, millet and mustard.

7.3. 14.7.3 Description of the Dunazug highlands

- Yearly mean precipitation sum: 580-600 mm
- Soil types: brown forest soil, chernozem brown forest soil.
- Number of sunny hours: 1400-1410
- Total heat sum: 2800-2900°C
Typical produced crops: the mountains are covered with forests, while hillsides are used as orchards, consisting mostly of peach, apple and almond. Crop production includes winter wheat, winter barley, rye, sunflower, peat, alfalfa and cockshead.

8. 14.8 Northern Hungary Mid-Mountains

- Highland of the Danube bend
- Nógrád basin
- Cserhát region
- Mátra region
- Bükk region
- Heves-Borsod basins and hill countries
- North Borsod highlands
- Tokaj-Zemplén highlands

8.1. 14.8.1 Description of the Danube bend highlands and the Nógrád basin

- Soil types: brown forest soil with clay illuviation, podzolic brown forest soil, alluvial soil.
- Yearly mean precipitation sum: 600-700 mm
- Number of sunny hours: 1350-1400
- Total heat sum: 2800-2900°C

- Typical produced crops: in addition to forest use, fruit production (especially) is significant. Produced crops include winter wheat, winter barley, spring barley, oat, sunflower, winter coleseed, alfalfa, pea and potato.

8.2. 14.8.2 Description of the Cserhát region

- Soil types: rusty brown forest soil, chernozem brown forest soil, chernozem, skeletal soils, alluvial soils.
- Yearly mean precipitation sum: 550-600 mm
- Number of sunny hours: 1380-1450
- Total heat sum: 2900-3100°C

- Typical produced crops: in addition to forestry, the range of crops produced on the ploughland is wide, including winter wheat, spring barley, oat, sunflower, winter coleseed, alfalfa and red clover. Pea is an especially important crop in the region, produced as greenpeas, dry pea and for sowing seed purposes on large areas. The herb and volatile oil production and processing plant in the area of Kerepestarcsa is the speciality of the region. Mustard, coriander, safflower, lavender, garden sage, chamomile, hyssop, melilot, anise and cumin are produced also for sowing seed purposes. In the area of Monor, several flowers and vegetables are produced for sowing seed purposes, in addition to herbs.

8.3. 14.8.3 Description of the Mátra region

- Soil types: brown forest soil, chernozem brown forest soil.
- Yearly mean precipitation sum: 600-700 mm
- Number of sunny hours: 1330-1350
• Total heat sum: 2700-2850°C

• Typical produced crops: mainly forest use, while grape and fruit production is carried out on the southern slopes. In the little area suitable for field crop production, the following crops are grown: winter wheat, winter barley, oat, peat, sunflower, alfalfa and tomato.

**8.4. 14.8.4 Description of the Bükk region**

• Soil types: brown forest soil, brown forest soil with clay illuviation, chernozem brown forest soil.

• Yearly mean precipitation sum: 650-750 mm

• Number of sunny hours: 1330-1360

• Total heat sum: 2750-2900°C

• Typical produced crops: winter wheat, autumn and spring barley, peat, sunflower, alfalfa, tomato, melon, sugar beet and red clover.

**8.5. 14.8.5 Description of the Heves-Borsod basins and hill countries**

• Soil types: brown forest soil, alluvial soils, skeletal soils.

• Yearly mean precipitation sum: 600-650 mm

• Number of sunny hours: 1360-1400

• Total heat sum: 2850-2950°C

• Typical produced crops: winter wheat, spring barley, rye, oat, winter coleseed, potato, fibre flax and pea; apple and melon in sandy areas.

**8.6. 14.8.6 Description of the North Borsod highlands**

• Soil types: brown forest soil, rendzina, alluvial soils.

• Yearly mean precipitation sum: 600-630 mm

• Number of sunny hours: 1340-1360

• Total heat sum: 2800-2900°C

• Typical produced crops: in the areas suitable for field crop production, mainly winter wheat, spring barley, oat, peat and red clover are produced.

**8.7. 14.8.7 Description of the Tokaj-Zemplén highlands**

• Soil types: acidic brown forest soil, chernozem brown forest soil.

• Yearly mean precipitation sum: 600-650 mm

• Number of sunny hours: 1360-1400

• Total heat sum: 2850-3000°C

• Typical produced crops: forest use is typical in higher areas and grape production is performed on the southern slopes. In areas suitable for field crop production, mainly winter wheat, spring barley, oat, peat, fodder beet and red clover are produced.
15. fejezet - 15. The basic elements of regional production. Correlation between regional varieties, biological based and production technologies

1. 15.1 The concept of region and its role in farming

The part of surface which can be naturally bordered, has uniform structure and can be characterised by the same system of interactions. The production site endowments of Hungary have a mosaic character which results from the surface, soil-related and climatic diversity.

A region consists of several interconnecting region types. The different region types can be distinguished based on the ecosystem analysis of the region. These types consist of closely interconnected ecological units and their groups. The classification of regions is based on topographical aspects, aiming at the examination of spatial structure. 35 mid-regions were identified in the hierarchic system of the classification of Hungary’s regions.

Regional production means utilisation in accordance with production site endowments and the growing of crops which adapt to the given region.

Elements of adapting to a region

- Taking region as a natural, social and economic unit as a basis.
- Production of crops and breeding of animals fitting the region.
- Proper crop rotation.
- Using different agrotechnics in each region:
  - environmentally friendly farming,
  - preserving tillage, soil protection,
  - soil conservation,
  - crop protection with preventive technology.
- Consideration of a region's ability to provide food for animals.

2. 15.2 Aspects of environmental friendly farming

Preserving biodiversity is important from the aspect of maintaining the ecological balance. The stability of natural ecosystems is promoted by higher diversity of species and this regularity is also true in the case of agroecosystems. The more colourful an ecosystem is, the more it is able to tolerate the changes of environmental factors.

A sustainable spatial usage system has to be established which – as an organic part of agricultural activities – provides the harmony of fundamental nature protection – environmental stability, as well as the production and consumption spatial functions.

Farmers need to follow the “human scale” principle and to be able to comprehend, keep track of and influence natural processes and their changes on a daily basis.

Elements stream in the biosphere cyclically. Considering this fact, it can be established that the maintenance of the soil-plant-soil, the soil-plant-animal-soil and the soil-plant-animal-human-soil cyclical processes on the
structural elements (plots, farms) of the space naturally structured by the biotope network is of fundamental importance, as well as their harmonious interconnection as a result of natural ecosystems, while maintaining the production cyclical processes, cycles, the material and energy flow. Environmental friendly farming can be performed only if the farmer adapts to the regional and production site-specific endowments. In addition to establishing a regionally adapted crop structure, the agrotechnical solutions to be applied also need to be adapted to the given region and production site. More specifically, soil preserving cultivation, soil protection soil conservancy without using fertilisers and preventive, technological crop protection is needed.

3. 15.3 Aspects influencing the sustainability and adaptability of crop production

Diversity. The fluctuation of crop productivity or the rate of organic matter breakdown is lower if the species diversity is higher. This recognition is especially important in agriculture, where it is favourable if yield is relatively stable from year to year.

Diversity is the basic requirement of sustainable agriculture:

• diversity of culture species,
• diversity of species living in the nature,
• genetic diversity,
• biotope diversity,
• land use diversity,
• farm size diversity,
• diversity of the farming system and the degree of intensity.

Farm sizes

In addition to developing the optimum plot sizes while preserving the regional character, feasibility of production methods must be adapted to production sites. During the establishment of the "human scale" farm size adapted to the environment, one must consider the following aspects:

• ecology
• soil protection,
• traditional land use,
• aesthetics,
• production,
• technological,
• economic.

Agroecosystems built on cyclic processes.

Elements in the biosphere flow in a cycle, creating the basic elements of maintaining a natural balance:

The self-regulatory ability of the

• soil-plant-soil
• soil-plant-animal-soil
15. The basic elements of regional production. Correlation between regional varieties, biological based and production technologies

- soil-plant-animal-human-soil cyclic processes decreased

Restoration of the cyclic processes is a key need of environmental friendly, sustainable environmental and regional farming.

4. 15.4 Main areas of adapting to a region

- Establishing the biological bases fitting the region, coupling and integrating them into a crop rotation.
- Using farming methods adapting to agroecologic endowments which are different in each region:
  - Cultivation
  - Soil protection
  - Soil conservation
  - Fertilisation
  - Sowing
  - Plant care
  - Crop protection
  - Harvesting

4.1. 15.4.1 Sowing structure, crop variety structure

Regional farming derives its objectives from the environmental conditions and traditions. The basic element of regional farming is the sowing structure adapting to environmental endowments, as well as the establishment of a plant species and variety structure.

Methods of adapting the sowing structure to the ecological conditions:

- choosing species and varieties whose agroecological needs are close to the production site endowments of the given area,
- breeding varieties which have agroecological needs that are compatible with the environmental conditions of the given area.

4.1.1. 15.4.1.1 Aboriginal and indigenous cash crops

Our culture crops are not of European origin. Different ethnic groups brought with themselves the varieties they had been producing. The time and method of bringing these varieties here are different. Most species are regarded domesticated or aboriginal, while some are considered to be “Hungaricum”. The domestication started 10-12 thousand years ago in the Middle East from where these varieties became widespread in the millennia to follow. The first cereals and legumes were selected by multiple selections. Due to the exclusive production of culture species, the other plant species started to become rare and vanish in the New Age. The diversity of culture species increases.

4.1.2. 15.4.1.2 Concept of regional variety, reasons for its existence

Plants of old times were put into production by means of mass selection, they used to be variety mixtures and they adapted to the environment, creating a balanced population. Due to the geographical and cultural mosaic character, the plant belts also became mosaic-like, which helped the development of regional varieties. The old Hungarian cereals and fruits were renowned all over Europe. As a result of their genetic endowments, the regional varieties are more tolerant to extensive conditions, they have potentially better quality than modern varieties, but they perform worse in terms of quantity. Until the early 20th century, regional varieties were produced, followed by varieties created by breeders. The fight for increased yield capacity constantly changed
15. The basic elements of regional production. Correlation between regional varieties, biological based and production technologies

The variety composition of the culture crops and reduced the period of producing each variety. In the period between the two world wars, the period of each cereal variety’s production was 15-20 years, but for today it was reduced to 4-5 years.

4.1.3. 15.4.1.3 Alternatives of preserving regional varieties

The collection and maintenance of old varieties, as well as the description of variety traits and characteristics are the duty of gene preservation.

The international coordination of plant gene resources has been carried out by the International Plant Genetic Resources Institute since 1993.

There are 80000 items of 1200 plant species in the 25 Hungarian gene banks as genetic reserves: During the “in situ” gene preservation, the regional varieties and local types are maintained in their original production sites under so-called isoclimatic and edaphic circumstances. The aim of “on farm” gene preservation is to place the genetic material in their site of origin to farmers and small gardens. It would represent a reliable solution of maintaining and propagation of old regional varieties if they could be involved in the extensive, mostly ecological farming performed on Sensitive Natural Areas. Their production would give way to the regeneration of areas which are suitable for regional production but were exhausted due to intensive production. It could improve the relationship between people and the environment and also open new perspectives for sustainable, quality regional farming.

4.1.4. 15.4.1.4 Significance of breeding regional varieties

Different natural endowments can only be properly utilised with our indigenous Carpathian varieties which adapted to the production site and specially bred regional varieties based on our own gene resources. It is an important characteristic of regional varieties that they are able to transform the natural resources – especially incoming radiation – of a given place with a rather high efficiency. Regional varieties should also be awarded state classification and it should be determined which areas they are suggested to be produced. Extensive varieties react to increasing expenditures with relatively low yield increase, but they provide significantly higher yield at a low level of expenditure than an intensive variety and their comfort zone is also much wider.

The breeding and production of alternative crops have to be supported by:

• utilising special production sites,
• biological protection (e.g. oilseed radish, the nematicide effect of phacelia),
• they play an important role in the regeneration and the maintenance of the productivity of the soil (e.g. alfalfa, lupin, hairy vetch, melilot on sandy soil, clover species),
• they can also be the element of production for non-food purposes (energy, biomass).

5. 15.5 Crop rotation adapted to regional farming

The crop rotation rich in species and the professional selection of green crops is the fundamental and most economical method of

• the maintenance and improvement of soil fertility,
• soil protection,
• preventive maintenance of the soil and plant health status.

It conforms to the ecological principle of crop rotation and diversity more than the production without rotation and it is also closer to self-regulating natural plant communities.

When preparing a crop rotation, it should be considered what impacts crop species have on

• soil,
15. The basic elements of regional production. Correlation between regional varieties, biological based and production technologies

- soil fertility,
- their impact on each other.

6. 15.6 Vegetable structure adapting to the region

The vegetable structure has to be adapted to the production site endowments of the given region and the production site.

From the environmental and economic aspects, the good solution is if the vegetable structure is put together in a way, that the main and supplementary species typical of the region and their aboriginal, indigenous or previously domesticated varieties should be included.

Based on the production site characteristics and production traditions of the given region, the crops to be produced can be classified in the following way:

- Main crop species
- Supplementary crop species
- Conditional crop species

7. 15.7 Cultivation adapted to the region

Cultivation adapted to the region aims at serving the needs of the plant to be produced and it considers the long-term effects on soil processes to be aspects of the same rank. The goal is to maintain and protect the productivity of the soil as a living system and to mechanically establish a soil physical condition which covers the need of the plant to be produced by regulating the processes going on in the soil. Soil structure is an important factor of its productivity. The constant crumby structure is the result of soil life, more specifically, the activities of microorganisms and earthworms. Therefore, the aim of each intervention should be to help the structure conversion activities of soil organisms, thereby improving the biological maturation of the soil and the establishment of its crumby structure. The cultivation of the past period could be characterised by trying to reach high average yields while soils were degrading and their productivity was decreasing. Therefore, the tools of cultivation have to be used to establish a cultivation system in the given area under given circumstances that is adapted to the soil type, its physical type, biological productivity and ecological tolerance, as well as the crop structure and crop cycle. In addition to other tools (e.g. crop rotation, production of perennial legumes, etc.), preserving cultivation and favourable soil structure play important role in soil protection as well.

8. 15.8 Soil conservancy and fertilisation adapted to the region

There is a two-way and rather close correlation between the processes going on in the soil and the vital processes of the plant. Therefore, the system of nutrient supply has to be developed in a way that the impacts on the plant, soil and the environment are considered with the same weight. The organic and inorganic nutrient resources act on soil life, soil activity, the nutritional conditions of plants, as well as yield quantity and quality in close correlation with the climatic, soil and agrotechnical factors. For this reason, the system of soil conservancy has to be established with all these factors in mind. It has become the key question of this system to determine the quantity and quality of organic matter, as well as the standard of organic matter management. The role of organic matter in soil productivity also has to be taken into consideration; therefore, their evaluation changes completely. As regards the specific (humus) and non-specific organic matter content of the soil, the following impacts have to be emphasised:

- the internal nutrients are released by means of their mineralisation and become accessible for plants,
- the organic compounds in the soil (enzymes, antibiotics, vitamins) have a direct physiological impact on plants,
15. The basic elements of regional production. Correlation between regional varieties, biological based and production technologies

• they have a direct effect on the physical characteristics of the soil, as well as its water, heat and air management, its volume mass and porosity, as well as the density of the solid part. They serve as an energy battery in the soil cover on the surface of Earth by means of their carbon and energy resources that is the indispensable requirement of the microbial processes going on in the soil,

• they fundamentally determine the general and special environmental protection capacity and compensation ability of the soil

The interventions which do not improve the humus balance of the soil play a significant role in establishing and maintaining soil productivity. However, the organic matter created during production is not able to provide the necessary amount of nutrient in itself. Only the common use of organic and artificial fertilisers is capable of providing a result which is acceptable from all aspects. Potential resources of soil conservancy include the following:

• crop and root residues, stem residues, green manure,

• farmyard manure, liquid manure, peat, other organic waste,

• microbial nitrogen fixation,

• fertilisers which supplement the above.

Soil conservancy is not the same as fertilisation. Although supplementary fertilisation could still be an important factor, the conditions of environmental management which considers rational and strategic aspects and that of adapting crop production that is efficient from both the economic and ecological aspects can only be established if it is combined with other soil conservancy methods.

9. 15.9 Environmental protection adapted to the region

Prevention means the synchronisation of biological, ecological and technological tools from the plant health care aspect. The methods of this synchronisation can be classified into two groups:

Indirect methods that do not require supplementary energy input and mostly serve prevention purposes:

• Technological tools (choosing the production site, crop structure, crop cycle, crop rotation, cultivation, fertilisation (including chalk replenishment), humus management, organic matter replenishment, sowing techniques, etc.).

• Breeding and growing resistant crop varieties

• Protection of useful animals (mainly the bird species which are natural predators of rodents and insects (bird protection) useful insects, predatory mites etc.).

Direct methods which need supplementary energy input and mainly aim at overcoming an already evolved epidemic:

• Biological tools (the youngest branch of practical crop protection, most of them are under development, e.g. the breeding and placement of useful insects, using bacteria and virus preparations).

• Physical and mechanical tools (mechanical weed control (stubble treatment, shallow cultivation, row-spacing cultivation etc.) thermal weed control (e.g. combustion weed control with flame throwers), using sex, light, smell, colour and soil traps (rodents, harmful birds, insects etc.).

• Chemical tools: the “most effective”, but also most dangerous tools of crop production. They can be used only to eliminate really severe damages. Preventive, regularly repeated, recipe-like sprayings should be stopped. Instead, these substances can be used in a targeted way only if the economic threshold value of the damage done is reached, based on the predictions of the monitoring service.
15. The basic elements of regional production. Correlation between regional varieties, biological based and production technologies

The most acceptable solution could be the preventive, technological crop protection (selection of the production site, crop structure, crop rotation, crop cycle, cultivation, humus management, the protection of resistant varieties and useful animals, biological, physical and mechanical tools) that could be coupled with a mild chemical control for damage prevention purposes if these tools are insufficient.

10. 15.10 Necessity and possibility of the improvement of the correlation system between crop production and the region

A few examples of factors spoiling the image of a region.

• Power plants built on rivers:
  • Secondary salinification
  • Groundwater sinking

• Industrial plants emitting harmful substances:
  • Soil acidity

• Irrational plot delineation:
  • Erosion, deflation

• Unprofessional irrigation:
  • Secondary salinification

• Careless manure treatment of large scale animal farms:
  • Contamination of drinking water

Healing the wounds inflicted in a region is a lengthy social duty.

A balance has to be established between crop production and the region. In order to do that, the endowments and the needs have to be closer to each other, which can be done in one way: Crop production has to be adapted to the region and its special characteristics have to be taken into consideration. Large scale farming was an obstacle in this respect. Today, the structure of farming changed, which is a good opportunity to draw farmers’ attention to the importance of regional farming.

11. 15.11 Requirements of the future agricultural farms

The agricultural farms of the future not only have to produce valuable food, but they should contribute to the protection of regions and the nature. They should improve the functional and aesthetic quality of our environment, support the rural society and protect their values.

Farms (the units of agricultural production) can be operated in two different systems based on production cycles.

Closed farms: the production processes are organised into cyclic processes and they have the following:

• Necessary amount of land needed for production.

• Enough farmyard manure for the maintenance of soil fertility.

• Area covering the food and litter need of the animals.

• Machinery and buildings needed for the operation of the farm.
The basic elements of regional production. Correlation between regional varieties, biological based and production technologies

- The amount of saleable products which provide the subsistence of the people living in the farm.

Open farms: they are unable to provide a natural balance within their own areas:

- Intensive, industry-like, integrated, specialised farming systems, which call for special expertise. They provide a relative security, but it also results in a great extent of dependence. In order to establish the environmental balance, the cooperation of farmers at a wider regional level is needed.

In order to establish the harmony of farm types and farm structures, it is necessary to utilise the advantages lying in the adaptation of traditional settlement and estate forms to the regional endowments. Such traditional estate forms are ranches, extensive farming, biological farms, while ranch entertainment can also be carried out. The settlement parts consisting of a few houses in the Őrség hill country is the perfect example: in addition to their farming activity, they deal with craftsmanship which has a great tourism potential.
16. fejezet - Questions:

1. Which are the most important environmental factors?
2. Which factors influence the utilisation of light?
3. How is it possible to prevent winter frost damages?
4. What are the adverse impacts of wind?
5. What does one have to strive during cultivation in order to preserve precipitation?
6. Which water management characteristics can be obtained from the pF curve of the soil?
7. How is the moisture prevention effect of stubble-stripping expressed?
8. How does soil loosening influence the heat capacity and the heat transfer capacity of the soil?
9. How can the air management of the soil affected with land use procedures?
10. How to categorise the tillage systems?
11. What is the succession of work phases in the case of the classic tillage order?
12. How can the cultivation be performed in the case of late summer and autumn sown crops?
13. Which are the main points of the tillage system of spring sown crops?
14. Which are the soil characteristics affecting the cultivation of the main soil types in Hungary?
15. How can stubble-stripping, basic cultivation and seedbed preparation be performed on brown forest soil, chernozem and marsh soil?
16. How can cultivation be performed on alkaline soil?
17. What are the guidelines of the cultivation of quicksand soil and humic sandy soil?
18. How can cultivation be performed on marsh soil?
19. Which are the deterioration processes which endanger the soil conditions?
20. Which factors cause the physical, chemical and biological deterioration of the soil?
21. How can the deterioration processes endangering the soil conditions be reduced?
22. Which are the main characteristics of the conventional system?
23. How can the tillage systems be categorised?
24. What is the aim of deep cultivation?
25. When is it needed to perform deep cultivation?
26. What are the consequences of soil compaction?
27. How can the deep cultivation of the soil be performed?
28. What are the tools of the deep cultivation of the soil?
29. Which are the main factors of creating the crop order?
30. Which are the factors influencing the crop composition?
Questions:

31. What kind of natural science knowledge is the crop cycle based on?
32. In the case of which crops can you use the tillage system based on cultivator?
33. In the case of which crops can you use the disc tillage system?
34. What is the aim of fertilisation?
35. Which are the factors influencing the effectiveness of fertilisers?
36. What kind of correlation is between fertilisation and each production technological element?
37. Which are the main nutrient supply principles?
38. How can the environmental damage caused by fertilisation be counterbalanced?
39. Which are the main aspects of performing land arrangement?
40. Which are the main factors eliciting and affecting erosion?
41. Which are the factors eliciting and affecting deflation?
42. How can alkaline soils be classified from the aspect of chemical improvement?
43. Which are the causes of soil acidity?
44. How and with what kind of substances can acid soils be improved?
45. How should liming be performed?
46. Which are the alternatives of improving the surface soil condition?
47. Which are the general and supplementary constituents of land use systems?
48. What are the main characteristics of the uncultivated, fallow and crop rotation land use systems?
49. Which are the advantages and disadvantages of the monoculture land use system?
50. What effect does irrigation have on the soil condition?
51. Which are the basic principles of cultivation under irrigated circumstances?
52. How can the infiltration of irrigation water into the soil be promoted?
53. What has to be done in the case of average or weak water permeability soils?
54. Why is deep tillage necessary under irrigated circumstances?
55. Which are the factors influencing the development of the crop structure?
56. Which are the large regions of Hungary?
57. Which are the regional units of the Great Hungarian Plain?
58. Which are the typically produced crops of the West Hungarian periphery region?
59. What is the concept of region and what are the elements of adapting to the region?
60. What is the concept of regional variety and what are the reasons for its existence?
61. Which are the requirements of the future agricultural farms?
62. How can the agricultural farms be classified based on their production cycle?
Questions:

63. How can crop species be classified based on the production traditions?
17. fejezet - Bibliography


HUZSVAI L., 2004. Agroökológiai modellek, Egyetemi jegyzet, Debrecen

HUZSVAI L., RÁTONYI T., 2004. Földműveléstan gyakorlatok, Egyetemi jegyzet, Debrecen


KREYBIG L. 1956. Az agrotechnika tényezői és irányelvei. Akadémiai Kiadó, Budapest


LÁNG I. 1980. Az agroökológiai potenciál országos felméréséről. Magyar Tudomány. XXV. kötet, 7. szám, Budapest


RAJKAI, K., 2004: A víz mennyisége, eloszlása és áramlása a talajban. Akadémiai doktori értekezés, MTA TAKI.

RÁTONYI T. 1999. A talaj fizikai állapotának penetrométeres vizsgálata talajművelési tartamkísérletben. PhD (doktori) értekezés, Debrecen


TAMÁS J. (szerk.) 2002 Talajremediáció. Debreceni Egyetem ATC, Debrecen


http://www.aardappelpagina.nl/explorer/pagina/soilwater.htm
http://corn.agronomy.wisc.edu/Management/L007.aspx
http://www.ndrcd.org/?id=40&page=Projects
http://cropwatch.unl.edu/web/tillage/advdisadv
http://interm.gtk.gau.hu/miau/remete/VEGNYOMD.html
http://tnfarchives.nofa.org/?q=article/building-soils-better-crops
http://milford.nserl.purdue.edu/weppdocs/overview/rill.html
http://www.thefreedictionary.com/strip-copping