混农林系统高价值木材生产准则

Guideline for valuable wood production in Agroforestry Systems

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1 AGROFORESTRY SYSTEMS

Fig. 1: Modern Agroforestry system in Breisach, Germany (Picture: H. Spiecker)

1.1 Definition of Agroforestry for this guideline

Agroforestry is the simultaneous cultivation of agricultural crops and trees on the same acreage. The agricultural land use is specified by the short rotation periods (1-10 years) whereas the forestry component is utilized in a long rotation cycle (20-40 years).

The interaction of the two Agroforestry components leads to specific growth conditions for each component. The knowledge about these conditions must be included in the management concept.

This guideline focuses on the management for valuable tree production in Agroforestry systems. Nevertheless the agricultural component will be considered in the guideline.

1.2 Special form of Agroforestry systems

Commonly the association of agricultural crops are annual crops like wheat, rice or maize. But also perennials can be added to the agricultural crops when the harvested takes place in short rotation cycles of 1-10 years. This can also be for example trees or bushes. In figure 2 is pictured an Agroforestry combination of Cherry trees (15 years old) and Poplar trees (2 years old) in Breisach, Germany.

Fig. 2: Agroforestry combination of Cherry trees (valuable wood) and Poplar trees (biomass production) in Breisach, Germany (Picture: A. Dörr)

1 混农林系统

图 1: 位于德国 Breisach 地区的现代混农林系统（图片提供者: H. Spiecker）

1.1 本准则对混农林业的定义

混农林业是指在同一块土地上同时种植农作物和树木。农地轮作周期短（1-10 年），而林地部分轮作周期长（20-40 岁）。

混农林业的这两个部分相互作用导致了每个部分的特定生长条件。在管理理念中必须纳入对这些条件的认识。

本准则侧重于混农林系统高价值木材的生产管理。尽管如此，本文也将考虑农业部分。

1.2 混农林系统的特殊构成

通常种植的农作物有小麦、水稻或玉米等一年生作物。但是，收获期为 1-10 年的短轮作周期的多年生植物也可算作农作物。例如，树木和灌木也可包括在内。图 2 所示的德国 Breisach 地区混农林组合中有樱桃树（15 岁）和杨树（2 岁）。

图 2: 德国 Breisach 地区的樱桃树（高价值木材）、杨树（生物质生产）
混农林组合 （图片提供者：A. Dörr）

This special form of Agroforestry where valuable wood production with long rotation cycles is combined with woody biomass production with short rotation cycles is the subject of the Sino-German-Cooperation Project ValWood. In 2009 a demonstration plot has been established at the ECTF in Pingxiang, China.
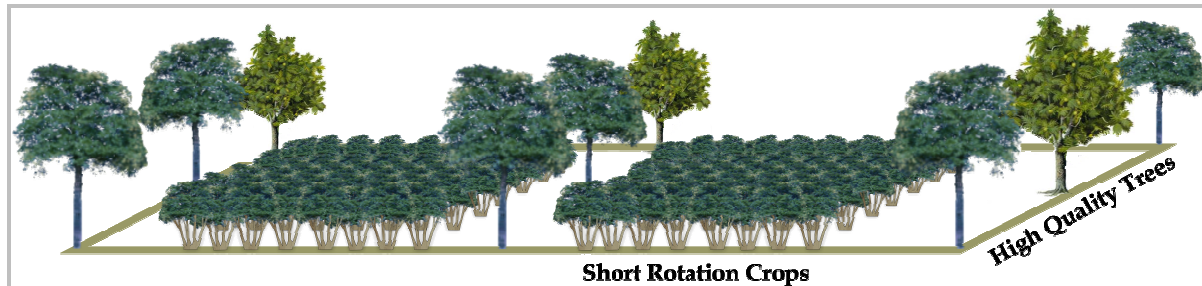

Fig. 3: Agroforestry design of the ValWood project in Pingxiang, China (Picture: J. Storch)

1.3 Economic advantages of Agroforestry systems

Diversification of the income (Risk minimisation)

- Long term increase of capital (for retirement pay, grand children, etc)

- Better added value on poor sites

- Wood production by ongoing agricultural use of the site

- Ecological and aesthetical upgrading of the landscape

这种特殊的混农林形式，即长轮作周期的高价值木材生产与短轮作周期的木质生物质生产的组合，是中德合作项目 ValWood 的主题。2009 年已在中国萍乡 ECTF 成立示范区。
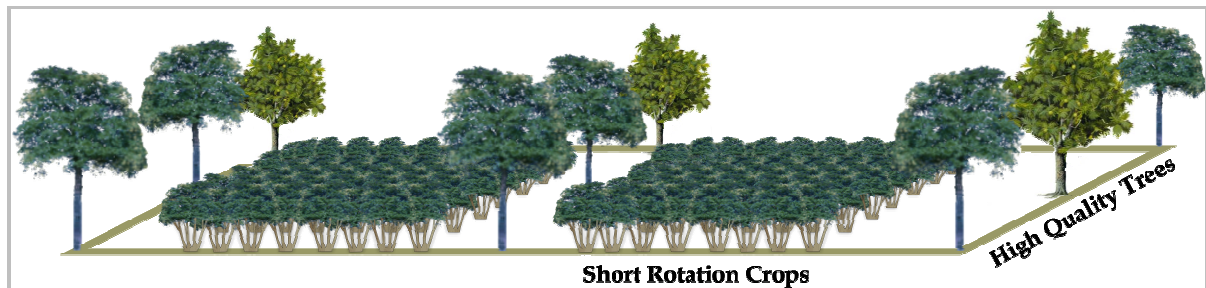

图 3: 中国萍乡 ValWood 项目混农林设计（图片提供者: J. Storch）

1.3 混农林系统的经济优势

收益多样化（风险最小化）

- 资本的长期增长（退休金、孙辈等）
- 更高的贫瘠土地附加值
- 同一地点同时进行农业利用及木材生产
- 改善土地的生态和景观

2 VALUABLE WOOD PRODUCTION IN AGROFORESTRY SYSTEMS

2.1 Special conditions for Agroforestry trees

The trees get planted in a far distance to each other, so that the conditions are different to a closed forest stand.	 **Fig. 4: Valuble trees after thinning in Breisach, Germany (Picture: H. Spiecker)**
The trees needs to be artificial pruned for valuable wood production and to guarantee enough light for the agricultural crops.	 **Fig. 5: Artificial pruned trees (Picture: H. Spiecker)**
The valuable trees remain at least 20-40 years before harvesting. This means that the conditions are totally different to the short rotation trees for biomass production.	 **Fig. 6: Open growth Cherry tree and dense Poplar stand in combination (Picture: C. Morhart)**

2 混农林系统的高价值木材生产

2.1 混农林树木的特殊条件

种植的树木彼此间距很大，因此其情况与封闭的林分不同。	 **图 4: 德国 Breisach 地区间苗后的高价值树木（图片提供者: H. Spiecker）**
为了生产高价值木材并保证农作物光线充足，需对这些树木进行人工修剪。	 图 5: 人工修剪过的树木（图片提供者: H. Spiecker）
高价值树木至少在 20-40 年后才可收获。这意味着其情况与生产生物质的短轮作周期树木完全不同。	 **图 6: 开放生长的樱桃树和密集的杨树林分组合(图片提供者: C. Morhart）**

2.2 Establishment of an Agroforestry system

2.2.1 Selection of trees

Essential for the tree species selection is an accurate site determination. The most important site characteristics are:

- Precipitation (amount and annual distribution)
- Water economy (water holding capacity, stagnant moisture)
- Early or late frost
- Soil-aeration
- Soil nutrient content

A mixture of different valuable tree species will avoid risks like:

- Infestation with vermin
- Site drift (by climate change)
- Price fluctuation at the wood market

Fig. 7: Cherry tree with very good genetic for valuable wood production

2.2.2 Planting

The planting space between the different trees is related to the crown width at the tree maturity. Thereby the tree maturity is defined by the intended target DBH.

A method for avoiding risks is to plant the trees in triplets (see figure 8), i.e. within a triplet the distance between the trees is 2 meters while the distance between the centres of the triplets is defined by the crown width at the tree maturity like explained before. Thus after some years of growth the best and most valuable tree can be selected out of one triplet. The other two trees of the triplet will be cut down.

2.2 混农林系统的建立

2.2.1 树木的选择

树种选择的要点是准确的地点测定。最重要的地点特征是：

- 降水（水量和年内分配）
- 节水 （蓄水能力、滞水湿度）
- 早或晚霜冻
- 土壤通气性
- 土壤营养成分

混合不同的高价值树种将避免以下风险：
- 病虫大批侵害
- 位置移动（由于气候变化）
- 木材市场的价格波动

图7:有生产高价值木材基因的樱桃树

2.2.2 种植

不同树木的种植间距与成熟树木的冠幅有关。因而树木的成熟由预定的目标胸径来定义。

规避风险的一种方法是树木三棵一组种植（见图8），例如，在一个三元树组内树木间距是2米，同时如之前解释过的那样，各三元树组中心距由成熟树木冠幅来定义。因此，经过多年的生长后，从一个三元树组中可选出最好并且最有价值的树。该三元树组中的另外两棵树将被砍掉。
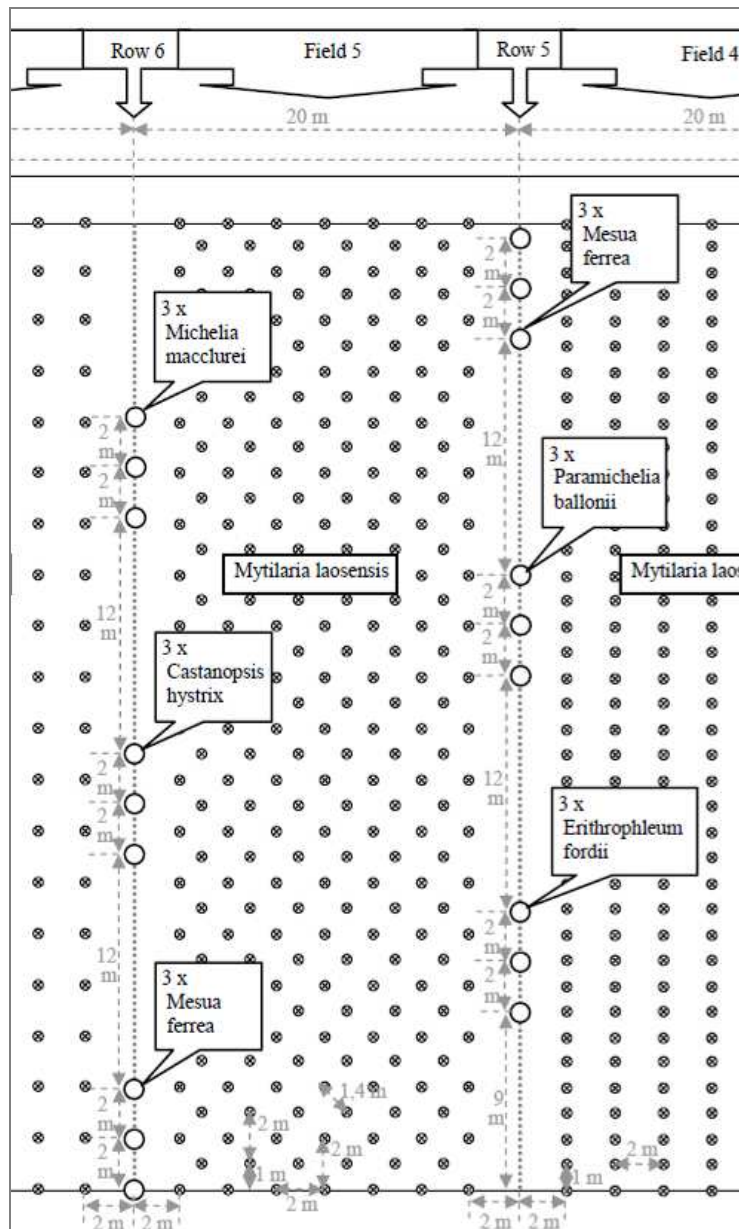
Fig. 8: Extract of the planting design of the ValWood demonstration Plot in Pingxiang, China (Doerr / Storch)

The quality of planting material has a high impact on the strike of the roots. The characteristics for good planting material are:

- No damaged ,distorted or kinked roots
- High amount of tender roots

A root pruning will avoid a distortion of the roots and results in a better strike of the roots:

- Pruning of the root tips at a diameter of 2-3 mm
- Especially at the bigger roots
- Not for adapting the size of the root ball to the size of the planting hole!!!
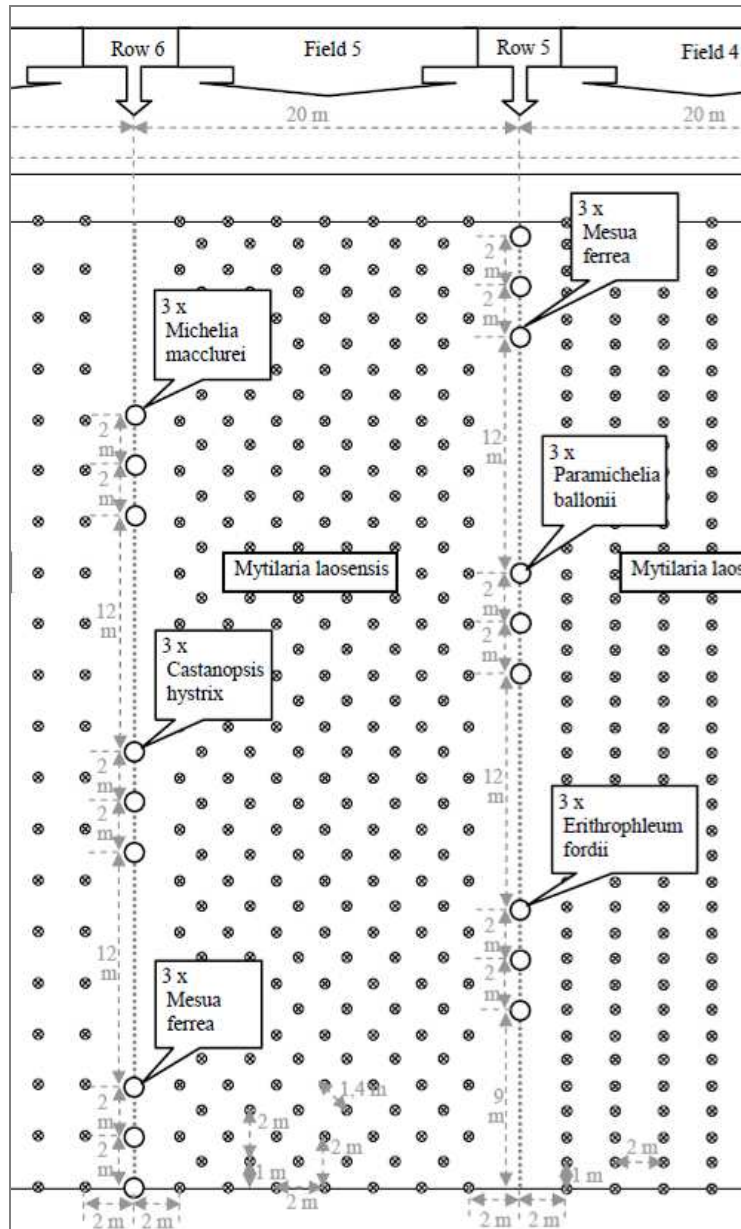
图 8: 中国萍乡 ValWood 示范区种植设计概要（Doerr / Storch）

种植材料的质量对扎根有很大的影响。好的种植材料的特点是：

- 没有损坏、扭曲或扭结的根
- 大量的嫩根

修剪树根将避免 树根扭曲并实现更好的扎根：

- 修剪直径 2-3 毫米的根尖
- 特别是在较大的根系
- 不是为了使根球的大小和种植穴的大小相匹配！！！

The most important criteria for a good planting are (see figure 9):	The most appearing mistakes at a planting are:
- Upright standing of the plant - A straight adjustment of the roots - Sufficient compression of the soil around the roots	- Not deep enough planting hole - Kinking of the roots - To heavy pruning of the roots

Fig. 9: Just planted nut tree in Kunming, China (Picture: H. Spiecker)

最重要的种植标准是（见图 9）：	最明显的种植错误是：
- 让树木直立 - 通过调整使根须向下 - 压实根部周围的土壤	- 种植穴不够深 - 根部扭结 - 根部过度修剪

图 9: 刚在中国昆明
种植的核桃树
(图片提供者: H. Spiecker）

2.3 Pruning Guideline

The problem is not so much whether we can afford to prune as it is whether we can afford NOT to do. (D.B. Cook, 1951)

Preface

In times of scarce resources and high labour costs it becomes more and more important to maintain or increase the value of the produced wood. Forest owners therefore increasingly tend to apply target-oriented management measures as future crop tree management, creation of site adapted mixed stands to stabilize forest structure, proper logging techniques to reduce impact on the remaining stand and artificial pruning to increase the value of the produced timber.

Effects of knots

The effect of knots on lumber grade depend on their size, number, and whether they are decayed or sound. Knots are affecting:

- strength properties of wood
- working qualities of wood (knots are harder than the tissue surrounding them)
- drying properties of wood (different drying behaviour results in twisting)

Why pruning?

Forest trees lose branches naturally over time as they become shaded by higher branches of the same tree or neighbouring trees. But since this process lasts a long time- depending on the tree species and the spacing - both living and dead branches leave knots in the wood.

Knottiness is the most important value-decreasing factor of wood. While branch-free boles realise highest prices at veneer markets, heavily knotty wood may not even compensate for the harvesting costs. The more valuable the end product is, the higher the requirements in respect to the raw material are. For instance veneer for furniture, music instruments, pieces of sport equipment or staves are made out of knot- free timber.

What is a "knotty core"?

The inner part of a tree, which contains branches, is called "knotty core". After branch death the tree produces clear wood, which surrounds the knotty core. Only the clear wood- the wood without branches- is usable for producing high-quality wood products as veneer. Therefore our intention should be to keep the dimension of the knotty core at a minimum.

2.3 修剪准则

与其说问题是我们是否承担得起修剪的后果，倒不如说是我们是否负担得起不修剪的后果。（D.B. Cook, 1951）

前言

在资源稀缺及劳动力成本高的时代，保持或提高所生产木材的价值变得越来越重要。因此，森林业主越来越倾向于应用以目标为导向的管理办法，例如目标树管理、建立土地适应型混合立地来稳定森林结构，利用适当的采伐技术来减少对剩余立地的影响，同时通过人工修剪来提高所生产木材的价值。

节的影响

节对木材等级的影响取决于节的大小、数量以及它们是否腐朽或健全。节会影响：

- 木材的强度特性
- 木材的工作质量（节比其周围的组织硬）
- 木材的干燥特性（不同的干燥特性会导致扭曲）

为什么修剪？

由于被本树或者邻近树木的高枝遮光，林木随着时间的推移会自然失去一些树枝。但由于这个过程会持续很长时间（取决于树种和间距），活枝和枯死枝都会在木材上留下节子。

多节是降低木材价值的最重要因素。无枝树干在单板市场可赚到最高价，与此同时多节子的木材甚至可能卖不出采伐成本价。终端产品的价值越高，对原材料的要求就越高。例如家具板、乐器板、体育器材部件或桶板均由无节材制成。

什么是"节子"

树内连接树枝的部分被称为"节子"。树枝死后，树的节子周围会产生无疵木材。只有无疵木材（没有树枝的木材）可作为单板用于生产高品质的木质产品。

因此，我们的目的应该是使节子的尺寸保持在最小水平。

It is only worth to prune potential future crop trees. We are selecting them by reason of the following criteria:

1) **vigour** (indicator: DBH and crown size both above average compared to the other trees in the stand, low tree height/DBH-ratio);

2) **timber quality** (indicator assessable from a standing tree: branchiness e.g. height of first green and dead branch, presence of forks, epicormic shoots, stem form, bark damage)

3) **distribution** (indicators: distance to the next crop-tree, distance to skid roads).

What is pruning?

It is possible to control knottiness of a tree with relatively little effort through cutting off branches from lower part of the stem. This operation accelerates the pruning process. The lowest part of the stem is known to be the most valuable part of the whole tree. By pruning the branches off the first length, the value of the end product wood can be increased enormously. Pruning promotes the production of stems with valuable knot-free timber. As a rule of thumb, the knot-free timber should be at least 20cm wide. Pruning in a proper way and in time increases the revenue considerably. One

has to think of it as an investment. If the trees are not pruned then one will maybe lose future income. Pruning operations can increase the value of a broadleaf wood by between 5 and 20 fold.

Fig. 10: Pruning methods, left scissors, right saw (Picture: H. Spiecker)

Time of year to prune

The point of time for pruning interventions strongly depends on the biological characters of the tree species to prune.

We distinguish two ways of pruning:

As a general rule it is necessary to **avoid pruning operations** during periods of very low temperature or severe drought!

唯一值得修剪的是未来潜在的主伐木

我们依据以下标准选择：

1) **活力**（指标：与该林分中的其他树相比胸径和冠幅高于平均水平，树高/胸径比率低）；

2) **木材质量**（立木评估指标： 分枝性，例如第一个绿色和死亡树枝的高度、分叉的存在、茎上枝、干形、 树皮损伤）

3) **分布** （指标：与邻近主伐木的距离、与伐木滑道的距离）。

什么是修剪？

通过在树干低处剪枝可轻松控制树木的多节问题。此操作加速了修剪过程。众所周知，树干最低部分是整棵树最有价值的部分。通过从第一段修剪掉树枝，可大幅提高终端木材产品的价值。修剪可促进树干高价值无节材的产出。根据经验说法，无节材至少应该 20 厘米宽。适当并且及时的修剪可大大提高收入。这应该被看作是一种投资。不修剪树木可能会失去未来的收入。修剪操作可以将阔叶材的价值增加 5 至 20 倍。

图10: 修剪方法，左图剪刀，右图锯

一年中修剪的时间

进行修剪介入的时间点主要取决于所修剪树种的生物特性。

我们对两种修剪方式的区分：

一般说来，**一定不能**在低温或严重干旱时期进行修剪操作！

1.) Pruning of dead branches

2.) Pruning of living branches

Pruning a dead branch never means intervention in the tree's leaf mass. Through encroachment in the naturally induced self-pruning process, it only promotes an earlier callus formation and accelerates healing processes than leaving the tree unpruned. Usually, when performed professionally, dead branch pruning never leads to injuries of the trees, which are resulting in a higher susceptibility to illnesses or diseases. Therefore, pruning dead branches could be done at any time of the year.

However, pruning living branches always means a certain intervention in the tree's living organs and the tree's leaf area. It also means creation of wounds, which are leading to a higher susceptibility of the tree to fungi or bacteria attacks, because we are intervening in a living organ. In temperate zones, pruning operations therefore are done generally in the period of fastest radial growth at the beginning of the growing season to promote a very fast healing of the pruning wounds.

Never forget your pruned trees in your forests! After pruning, the trees need special care, since they are strongly weakened by the pruning intervention. By releasing the tree's crown after each pruning intervention, we make sure, that the trees will be sufficiently provided with light and nutrients.

Timing of first pruning

As already mentioned, the objective of pruning operations is to minimize the dimension of the knotty core in the inner part of the first length. However, this can only be achieved by starting pruning measures as early as possible. Since veneer companies require a certain width of knot-free wood, it seems feasible to use the diameter at breast height as a criterion when deciding the timing of the first intervention. The earlier the pruning, the smaller the knotty core and the faster the wounds of pruning will be closed.

Diameter of branches to cut

When considering branch size, the process of wound occlusion should also be taken into account. Healing over of wounds is influenced by a complex of factors, as the position of the cut, the length of stubs, the smoothness of the cut and the diameter growth of the particular tree at the location of the wound. The most important factor, however, that influences the time

We should remove branches with a diameter of **more than 3cm** at first and in any case.

needed to occlude the pruning wound, is the diameter of the pruned branch. As a general rule it can be stated, that conspicuous thick and steep branches should be removed first, even if they are situated in

1.) 修剪枯死枝

2.) 修剪活枝

修剪枯死枝决不意味着干预树的叶重量。通过自然引发的自我修剪过程的侵蚀，修剪枯死枝相比于不修剪仅仅是提早了胼胝体的形成并加速愈合过程。通常，如果操作专业，枯死枝修剪决不会造成使树木对疾病或病害更敏感的损伤。因此，可以在一年中的任何时间修剪枯死枝。

然而，修剪活枝通常会干扰到树的活组织及树叶部分。由于我们干预的是活着的组织，这也意味着创伤的形成，而这些创伤会使树木更易受到真菌或细菌侵害。因此，在温带地区，修剪操作一般在生长季节初期径向生长最快的时期完成，以促进修剪伤口快速愈合。

一定不要忘记林子里修剪过的树！经过修剪的树需要特别照顾，因为修剪干预严重削弱了这些树。通过每次修剪干预后疏松树冠，我们确定这些树将得到充足的光和养分。

初次修剪的时机

正如前述，修剪操作的目的是尽量减小第一段树干内的节子。但是，只有尽早开始修剪才能实现。鉴于单板公司对无节材宽度有专门的要求，看来可以胸径为标准来决定初次干预时间。修剪越早，节子将越小且修剪伤口闭合越快。
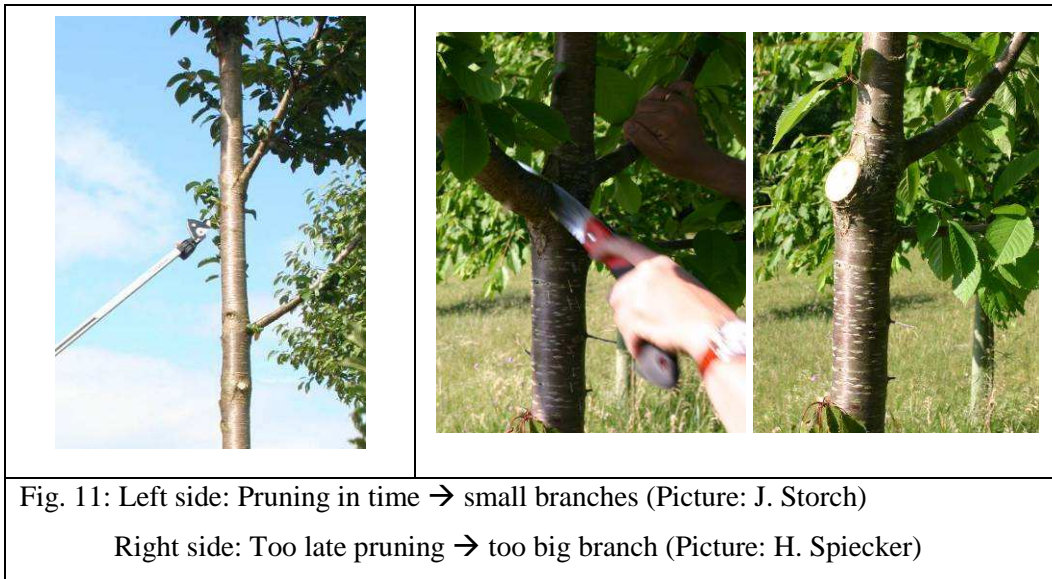
剪切树枝的直径

考虑树枝尺寸的同时也应考虑伤口闭合过程。有多个因素影响伤口愈合，例如切口位置、残枝的长度、切口的平滑度以及伤口处的直径生长。然而，修剪伤口所需要的闭合时间主要由被修剪树枝的直径来决定。一般来说，

我们应首先并在任何情况下都要切除直径**超过3厘米**的树枝。

higher positions in the crown, because those branches with high vigour are growing much faster in diameter than others. This approach is called "anticipatory pruning".
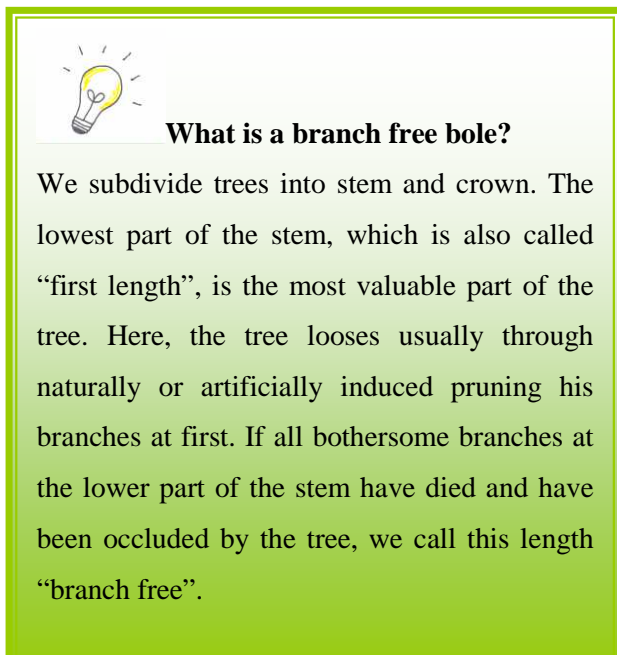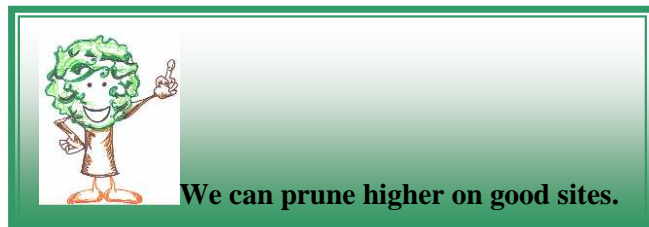

Fig. 11: Left side: Pruning in time → small branches (Picture: J. Storch)

Right side: Too late pruning → too big branch (Picture: H. Spiecker)

Conclusion:

Branches should be pruned as small

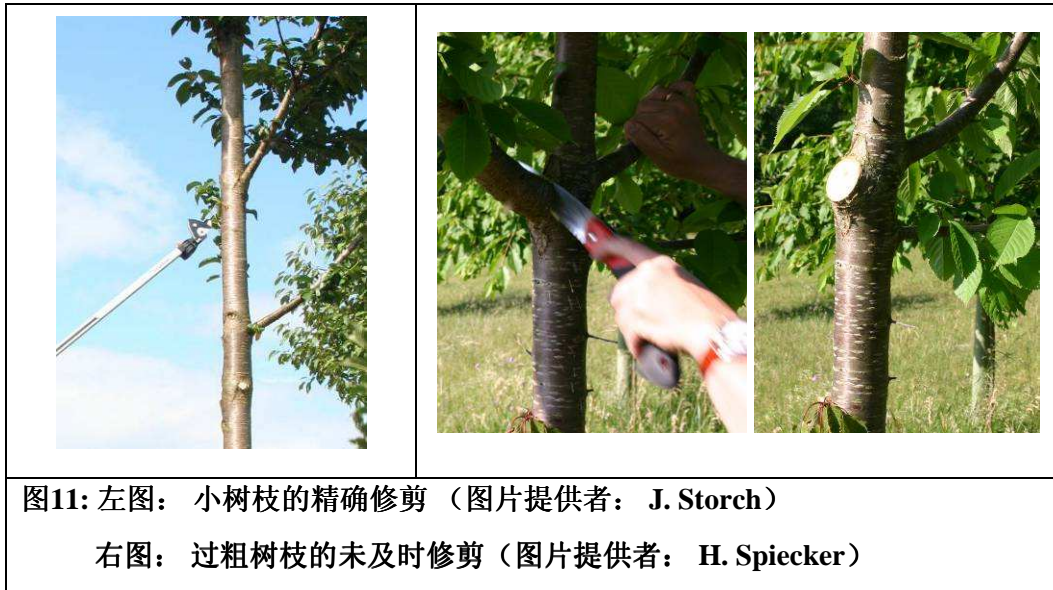**as possible (less than or equal to 3cm).**

Pruning height

The pruning height depends on several aspects:

First, we keep in mind, that the length of the branch free bole generally should not exceed one third of the total height, the tree reaches at the end of the rotation time, to obtain a vigorous crown. As we know already, this height depends on the tree species and the site. On poor sites, for example on very dry or shallow soils, trees would never grow as high as they would grow on very rich sites. In conclusion, we can state, that the pruning height depends on the biological character of the tree species as well as on the site quality.

We can prune higher on good sites.

What is a branch free bole?

We subdivide trees into stem and crown. The lowest part of the stem, which is also called "first length", is the most valuable part of the tree. Here, the tree looses usually through naturally or artificially induced pruning his branches at first. If all bothersome branches at the lower part of the stem have died and have been occluded by the tree, we call this length "branch free".

应首先切除明显很粗并且很陡的树枝，即使他们位于树冠部分较高的位置也不例外，因为这些高活力树枝的直径生长比其他树枝快很多。这种方法被称为"预见性修剪"。

图11: 左图： 小树枝的精确修剪 （图片提供者： J. Storch）

右图： 过粗树枝的未及时修剪（图片提供者： H. Spiecker）

结论：

修剪树枝应越小越好

（小于或等于3厘米）。

修剪高度

修剪高度取决于几个方面：

首先，我们要注意，无分叉树干的长度通常不应超过树木轮作周期结束时总高度的三分之一，以便获得一个有活力的树冠。 正如所知，这个高度取决于树种和地点。在贫瘠的地点，例如在非常干燥或者浅层土壤中，树木长不到在沃土中那样的高度。我们的结论是，修剪高度取决于树种的生物特性以及生长地点的环境。

在好地点我们可以修剪得高一点。

什么是无枝树干？

我们将树细分为树干和树冠。树干最低部分，也叫做"第一段"，是树最有价值的部分。在这部分，通常树首先通过自然或人工修剪消减它的树枝。如果树干低处所有麻烦的树枝都死亡并且被树封闭，我们称这段为"无枝"。

Second, we have to have a careful look at the requirements of the veneer processing companies. In Europe, clear bole lengths which equal a multiple of 2.5m are very popular among the processing companies since this is a common processing length. Finally the pruning height depends on the market. When the price is very sensitive to the stem diameter, maximum pruning height should be lower in order to accelerate earlier diameter growth.

Fig. 12: High pruning by Guo Wenfu, ECTF (Picture: H. Spiecker)

Conclusion:

- **The length of the branch-free bole generally should not exceed one third of the total height, the tree reaches at the end of the rotation time.**

    E.g.: Total tree height at the end of the rotation time: 30m. Pruning height: 10m.

- **Clear bole lengths, which equal a multiple of 2.5m, are very popular among the processing companies.**

　　第二，我们必须仔细看看单板加工企业的要求。在欧洲，2.5米倍数长度的无疵树干段很受加工企业欢迎，因为这是常见的加工长度。最后，修剪高度取决于市场。如果价格对树干直径很敏感，那么最大修剪高度应该适当降低以加速直径较早生长。


**图12:郭文福（音译）在进行高处修剪，
ECTF （照片提供者：H. Spiecker）**

结论：

- **通常无分叉树干的长度不应超过树木轮作周期末总高度的三分之一。**

  例如：轮作周期末总树高：30米。修剪高度：10米。

- **无疵树干段，长度为2.5米的倍数，很受加工企业欢迎**

We distinguish **two phases of valuable wood production**:

First phase (1): During the first phase, the trees should loose their branches either through naturally occurring self-pruning by increased shading or through artificially induced pruning operations. After a certain time, which length strongly depends on the growth characteristics of the particular tree species as well as on the specific site conditions, the desired length of a branch free bole is produced. Generally, the length of the branch free bole should not exceed one third of the total height, the tree reaches at the end of the production time. This is because the tree needs also a big crown to grow in diameter (see second phase). In turn, the total height of a tree at a given age depends on the tree species and on the site!

Second phase (2): The tree lost his branches at the lower part of his stem and occluded the wounds? Good! But not enough! During the second phase we have to take care about the diameter increment. For this purpose, we release the crown of the tree heavily. Whereas the ultimate aim of the first phase was to make the branches disappear, we are now looking very carefully at the tree's crown. Foresters usually state, that the crown base should be maintained at the same height over the remaining production time. In practice, this means that no further branch should die anymore. Bearing this in mind, we have a powerful tool to control diameter growth
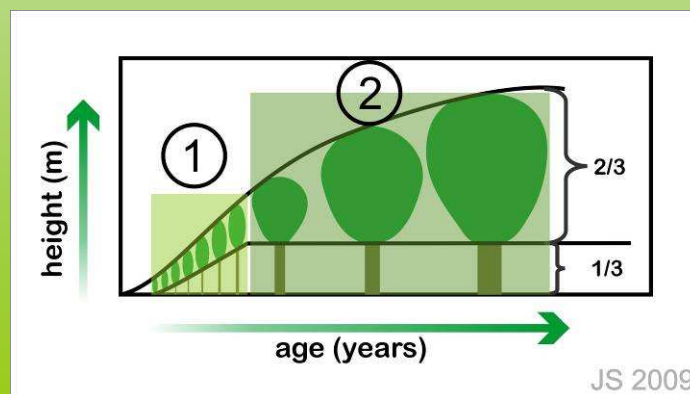

Frequency of pruning operations

Pruning should remove no more than one third of the living crown at each pruning lift. If more is removed, first diameter growth and, after heavily pruning of more than 50 percent of the total crown, also height growth will be reduced. But, as already mentioned, also the branch diameter plays an important role in pondering pruning operations. Pruning all branches at once at a very early development stage, when all branches are small would lead to a significant loss in tree vigour. Pruning all branches at once at a later development stage of the tree to obtain the required one third crown length would mean to injure the tree very severely, since the branches to cut off will have a large diameter. Both ways do not allow for fast production of knot free timber on healthy and vigorous

我们对**高价值木材生产两个阶段**的划分：

第一阶段 (1)：在第一阶段，树木应通过自然发生的自我修剪或者通过人工修剪消减树枝。经过一段时间，其长短取决于特定树种的生长特性以及特定的生长地点条件，生产出理想长度的无分叉树干。通常来说，无分叉树干的长度不应超过树木生产时间期末总高度的三分之一。这是因为树木也需要大树冠来增大直径（见第二阶段）。相应地，树在给定年龄的总树高取决于树种和生长地点！

第二阶段 (2)：树木失去其树干低 处的树枝并且封闭伤口？好！但不够！在第二阶段，我们必须留心直径增量。为了这个目的，我们大量消减树冠。第一阶段的根本目的在于使那些树枝消失，而我们现在则应密切关注树冠。林业工作者通常认为，树冠基部在剩余生产时间里应保持在同样的高度上。事实上，这意味着未来不应再有树枝死亡。记住这点，我们有控制直径生长的强有力工具。
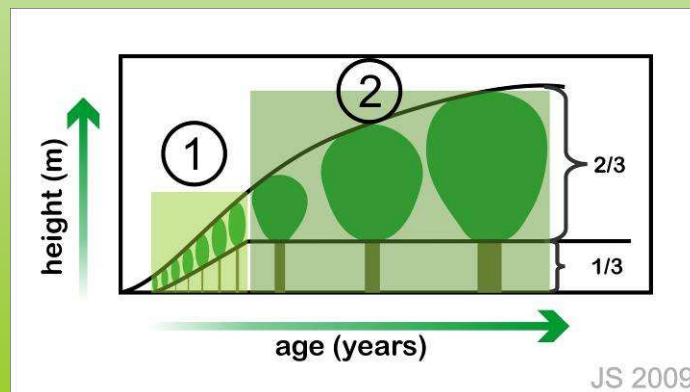
修剪操作频率

　　每次修剪所消减量不应超过活树冠的三分之一。如果超过了，首先会殃及直径生长，然后在超过总树冠50%的过量修剪之后，树高生长也将被缩减。但是，正如前言，在考虑修剪操作时应重点考虑树枝直径。在树枝生长很早期的阶段所有树枝都很小，这时一次性修剪掉所有树枝将严重损害树木活力。当所有树枝到了树木生长晚期阶段时再一次性修剪以获得所要求的三分之一树冠长度将会严重伤害树木，因为被砍掉的树枝直径会很大。要在健康并且有活力的树上快速生产无节材这两种方法均不可取。

trees. As a compromise between obtaining tree vigour and qualifying the tree at a very early development stage, pruning operations should be repeated. We recommend pruning within intervals of two to three years. A very fast growing tree species might need a denser frequency of pruning operations to avoid branches to grow over 3cm in diameter.

Conclusion: Fast growing tree species need a denser frequency of pruning operations.

How many trees to prune

Pruning is connected with high investment costs. Hence it seems reasonable to limit the pruning operations only on the best and most vigorous trees in one stand, the future crop trees.

Simple rule for broadleaves:
DBH * 25= distance between crop trees

For this reason, the number of trees to prune equals the number of future crop trees in one stand. It is possible to calculate the number of future crop trees, since crown diameter and DBH are closely related. By assuming a certain crown cover rate, it is possible to calculate the number of future crop trees for a desired DBH. As pruning up to 2m height is cheap at the beginning in addition to the future crop trees additional trees may be pruned.

Conclusion: The number of trees to prune equals the number of future crop trees in one stand.

Pruning practice

Pruning cuts should be made so that only branch material is removed and stem tissue is not damaged. Proper pruning techniques lead to a fast occlusion of wounds, whereas poor pruning techniques can lead to heavy injuries, from which the tree might never fully recover.

Therefore, it is very important to spend some time in studying pruning techniques and to invest some money in sharp pruning scissors or saws.

We can prune **dead branches** in much the same way as live branches. We make the pruning cut just outside of the ring of wound wood tissue that has formed, being careful not to cause unnecessary injury. **Branches without collar** should be removed also outside the branch bark ridge.

作为获得树木活力以及使树木在早期生长阶段就变得合格之间的折中方法，修剪操作应该不断重复。我们建议间隔2-3年修剪。生长非常会的树种可能需要比较密集的修剪操作频率以避免树枝直径生长超过3厘米。

结论：生长迅速的树种需要比较密集的修剪操作频率。

修剪多少树

修剪关系着高投资成本。因此修剪操作仅局限在林分内最好并且最有活力的树，即未来的主伐木比较合理。

阔叶树的简单规定：

胸径 * 25= 主伐木间距

因此，所修剪的树木数量等于同一林分内目标树的数量。统计目标树的数量是可能的，因为树冠直径和胸径紧密相关。假定一个植被覆盖率，就可能计算出理想胸径的目标树数。由于一开始修剪到 2 米所费不多，所以除了目标树之外可修剪更多的树。

结论：所修剪树木数量等于同一林分内目标树的数量。

修剪操作

应做成修剪切口，以便在不破坏树干组织的情况下仅移除树枝部分。恰当的修剪技术会使创口快速封闭，而差的修剪技术则会引起严重的伤害，由此树木可能无法完全恢复。

我们可以用与活枝几乎一样的方法修剪**枯死枝**。我们让修剪切口就在已成形的木材组织创口圈外，小心不要引起不必要的伤害。**没有枝瘤的树枝**也应从枝皮脊梁外移除。

因此，花一些时间学习修剪技术并且花一些钱在锋利的修剪剪刀或锯上很重要。

Pruning Cuts

A good cut begins just outside the branch bark ridge and angles down away from the stem of the tree, avoiding injury to the branch collar. Make the cut as close as possible to the stem in the **branch axil**, but outside the branch bark ridge, so that stem tissue is not injured and the wound can occlude in the shortest time possible.

Pruning practices that delay occlusion and harm trees

Stub cuts leave a branch stub by cutting too far from the stem. The wound closure is delayed because the woundwood must occlude the stub that was left. They provide entry to canker fungi that kill the cambium, delaying or preventing woundwood formation.

Flush cuts made inside the branch bark ridge or branch collar, result in pronounced development of woundwood on the sides of the pruning wounds with very little woundwood forming on the top or bottom.
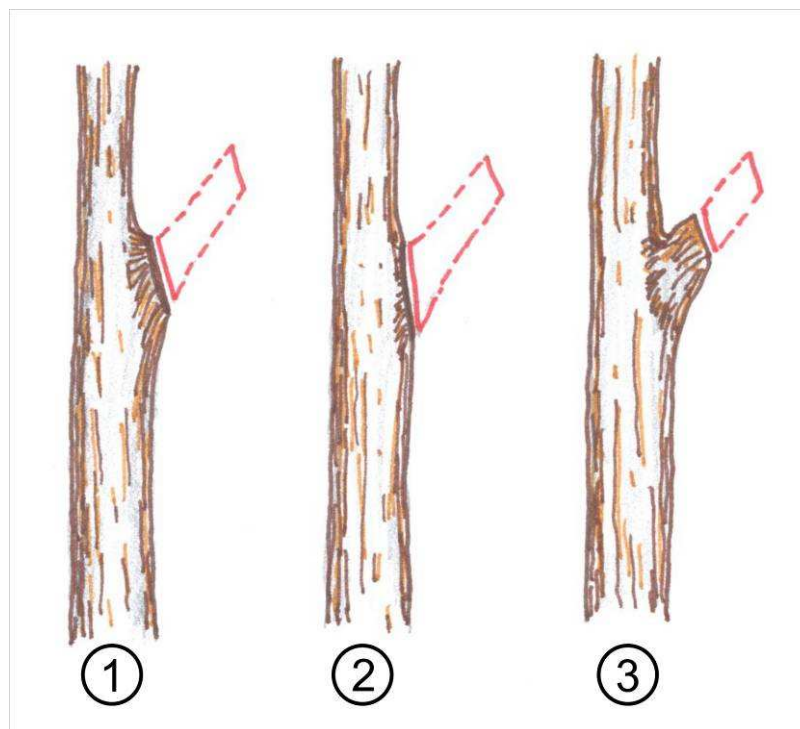

Fig. 13: 1.)Good pruning practice, 2.) Poor pruning practice (Flashcut), 3.) Poor pruning practice (stub cut)

Flush cuts severely injure stem tissues and can result in decay. They led to two to three times bigger wounds than branch collar cuts, which are resulting in much more discoloration in the woody tissue. Additionally, flush cuts led to extended cambial dieback at the wound edges compared to branch collar cuts.

修剪切口

好的切口在树枝明显突起外开始并且离开树干向下，避免对枝瘤的伤害。使切口尽可能接近**枝腋**里的树干，但要在枝皮脊梁的外部，以便树干组织不被伤害并且创口能在尽可能短的时间内封闭。

耽误封闭并且伤害树木的修剪操作

中切法 由于切的离树干太远而留下残枝。创口封闭被延迟因为受创木材必须封闭留下的残肢。这些残枝给 杀死新生组织的腐烂真菌提供了通道，延迟或者阻碍受创木材的形成。
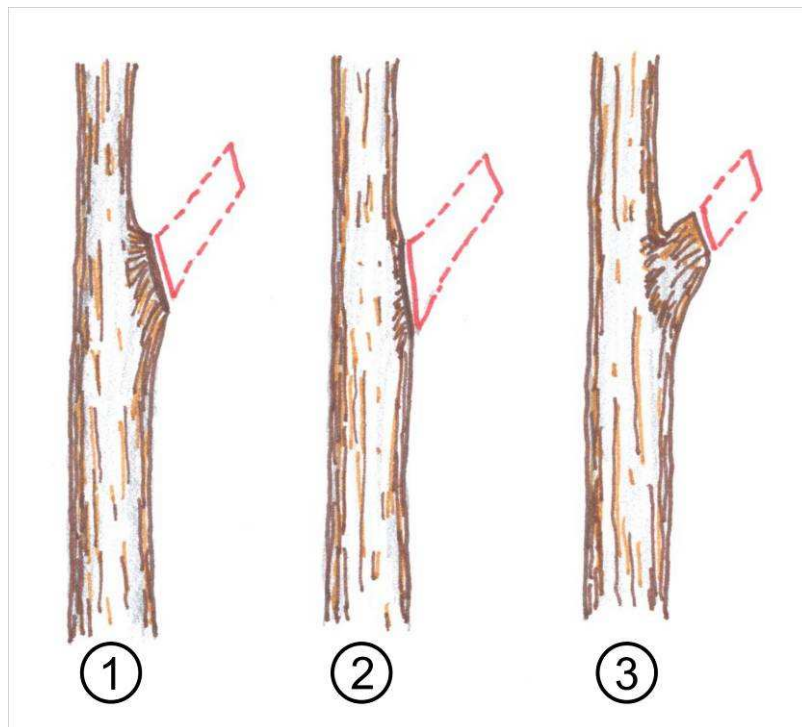
平切法 做在枝皮脊梁或者枝瘤内，导致修剪创口处受创木材的显著生长，而在顶部或底部没有受创木材形成。

图 13: 1.）好的修剪操作，2.）差的修剪操作（平切法）， 3.）差的修剪操作（中切法）

平切口严重伤害树干组织且会引发腐朽。它们会导致比枝瘤切口大2-3倍的创口，这些创口会引发木质组织严重变色。另外，相较于枝瘤切口，平切口会导致更大面积的创口边缘形成层枯死。

We can **evaluate the quality of pruning** cuts by examining pruning wounds after one growing season. If pruning has been carried out in a proper way, a concentric ring of wound wood will form.

Fig. 14: Two pictures left: Good pruning practice Cherry (Pictures: J. Storch, H. Spiecker)

One picture right: Poor pruning practice at Mytilaria→stub cut (Picture: H. Spiecker)

Conclusion:

- **No stub cutting**
- **No flush cutting**
- **No bark ripping**

Fig. 15: Pruning tools (picture: J. Storch)

Pruning tools

Proper tools are essential for satisfactory pruning.

The smoothest cut can be achieved by using a pruning scissor. They are also available with telescopic poles. A ladder therefore is not needed during the first pruning operations. During the last pruning measure, when it comes to prune branches in more than 7m height, a ladder is necessary. If in exceptional cases larger branches of more than 4cm in diameter have to be pruned, saws are a suitable tool. Unlike most other saws, pruning saws are often designed to cut on the "pull-stroke." All tools should be kept clean as well as sharp.

我们可以通过考核一个生长季后的修剪创口**评估修剪切口质量**。如果修剪方法恰当，将会形成一个同轴的创口圈。

图 14: 左侧两张图： 樱桃树好的修剪操作（图片提供者： **J. Storch, H. Spiecker**）

右侧一张图：壳菜果差的修剪操作➔中切法（图片提供者： **H. Spiecker**）

结论：

- 不要中切

- 不要平切

- 不要撕坏树皮

修剪工具

修剪工具对于符合要求的修剪是必不可少的。

用修剪剪刀可以得到最平滑的切口。用伸缩杆也可以达到同样效果。因此在第一次修剪操作时并不需要梯子。在修剪末期，当修剪高于7米的树枝时，必须要有梯子。如果出现例外情况，要修剪直径超过4厘米的较大树枝时，锯是比较合适的工具。 与其他大多数的锯不同，修剪锯通常被设计为通过"拉-划"来切。所有的工具都应保持干净、锋利。

图 15:修剪工具
（图片提供者： **J. Storch**）

2.4 HARVEST TIME

The maturity of a tree is defined by its DBH. This is caused by the fact that the diameter of the bole is influencing the market price. For broadleaves the general rule is: the bigger the bole is, the higher is the market price per cubic meter if the wood quality stays equal.

Nevertheless the time for harvest should not be set too late because old trees are susceptible for rottenness or other diseases that could decrease the price.

At the end the designated target diameter as well as the current market situation will determine the harvest time.

2.4 收获时间

一棵树的成熟由其胸径来界定。这是因为树干的直径会影响其市场价格。阔叶材的一般规律是：木材质量相同的情况下，树干越大，每立方米的市场价格就越高。

尽管如此，收获时间也不应太晚，因为老树易受腐朽或者其他会降低其价格的疾病的影响。

最后，预定的目标直径以及当前的市场情况会决定收获时间。

3 ADDITIONAL GUIDELINES FOR THE TRAINING WORKSHOP IN PINGXIANG 2011

3.1 Crop tree management for high value

The „future crop trees" are the value producers. This includes economic and ecological values. Efficient forest management focuses on these future crop trees.

Selection criteria of future crop trees:
  (1) Value (e.g. quality; most relevant trees for achieving the management objective)
  (2) Vitality (competitive superior trees, adapted to site conditions)
  (3) Special distribution (enough space between these crop trees until the end of their life)

Time of selection
  (1) When measures for improving the growth are needed (pruning, thinning)
  (2) When superiority of the tree can be predicted

Fig. 16: High value Oak tree in Germany

Number of future crop trees to be selected:
  (1) Not more than the number of trees that can grow on an area at the time of harvest

Treatment of future crop trees:
  (1) Improve value (pruning natural or artificial)
  (2) Stimulate growth (dimension of stem, tree vitality)

The principle: Aim oriented measures have to be taken at the right moment at the right location "precision management" or "intelligent management" - … efficiency = low input and high output of management.

How to calculate the area occupied by a tree tree:
    F = crown projection area + space between crowns (for example 30% of the area).
How to calculate the distance to the next tree:
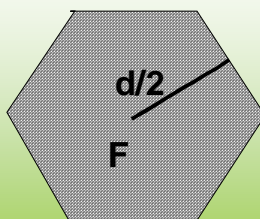
$$d = 2x \sqrt{\frac{Fx\sqrt{3}}{6}}$$

Example 1: If F (occupied area per tree) is 100m^2 then d (distance to the next tree) is 10.75m
Example 2: If F (occupied area per tree) is 125m^2 then d (distance to the next tree) is 12.01m

3 操作指南补充内容 (供 2011 年凭祥培训班使用)

3.1 高价值目标树经营

> 目标树是林分价值的创造者，包括经济价值和生态价值。林分高效经营的焦点要围绕这些目标树的经营目标树。

目标树的选择标准：
   （1）高价值（选择高品质的树木以达到经营目的）。
   （2）高活力（适应立地环境的竞争力强的优势木）。
   （3）空间充足 （保证在采伐之前，保持目标树有充足的生长空间）

进行目标树选择的时间：
   （1）需要采取措施促进生长时（如修枝，间伐）。
   （2）··木能被可靠预测的时。

图 16: 德国的高价值橡树

选择目标树的数量：
   （1）所选目标树的数量不超·采伐·树木的数量（注：即目标树选定后不再间伐，要一直长到采伐期）。
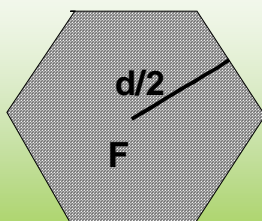
目标树的处理
   （1）通过自然整枝或人工修枝提高价值。
   （2）采取促·径级的生·以及提高·木生活力等措施促·树木生·。

   原则：目标树定向经营措施须适时适地开展。"精确"、"科学"和"高效"的经营管理意味着低投入和高产出。

如何测量一棵树所占的面积？
         单株所占面积 =树冠投影面积+树冠之间的面积（比如其面积的 30%）
如何计算相邻两树之间的距离？

$$d = 2x \sqrt{\frac{F x \sqrt{3}}{6}}$$

例 1：如果单株所占面积是 100 m²，那么到下一棵树的距离就是 10.75m。（注式中 x 为乘号）
例 1：如果单株所占面积是 125 m²，那么到下一棵树的距离就是 12.01m。

3.2 Pruning ladder system "DISTEL II"

To be able to prune higher than 7m, a special ladder system is needed. The ladder also assures ergonomic working conditions for pruning branches that are thicker than 4cm

Components of the "DISTEL II" system:
  (1) The ladder itself consists of four elements for pruning heights up to 11 meters. The base segment (8 rungs, 2.20 m) can be easily combined with up to three additional elements (each with 8 rungs, 2.10m)
  (2) Safety harness
  (3) Steel holding rope with rescue loop and ratched straps to secure ladder
  (4) High-performance saw with leather quiver

Procedure:
  (1) Put the base segment on the tree first and do pruning in reach height
  (2) It is recommended to lead the saw with both hands or with alternating hands. This will prevent exhaustion of your arm and improve pruning quality
  (3) According to the work progress further ladder segments can be attached by a special connection system

Fig. 17: Usage of the ladder system „DISTEL II" for pruning Cherry trees of an agroforestry system in Germany

R Relief cuts 1 and 2
F Final pruning cut
- - - Wrong pruning cuts
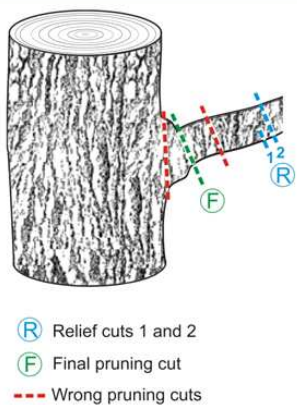
Correct pruning technique of a thick branch:

- Take care that no parts of the bark rip off!
  ➤ For thicker branches, relief cuts (blue lines) need to be carried out first, before the residual stump of the branch is removed (green line)
- The stumps of the branches should be kept as short as possible
- Injuring the branch base or leaving behind long branch stumps should be avoided (red lines)

Advantages:
  (1) High performance
  (2) Ergonomic working process
  (3) Superior pruning quality
  (4) Safe working with full-body harness
  (5) Possibility to prune thick branch-diameters in higher parts of the tree

3.2 "迪斯泰 II"高空整枝梯组的应用

为了能够在超过 7 米高的树干上进行修枝，需要一个特制的梯子。梯子可以保证人体在正常条件下工作，可以去除直径超过 4cm 的枝条。
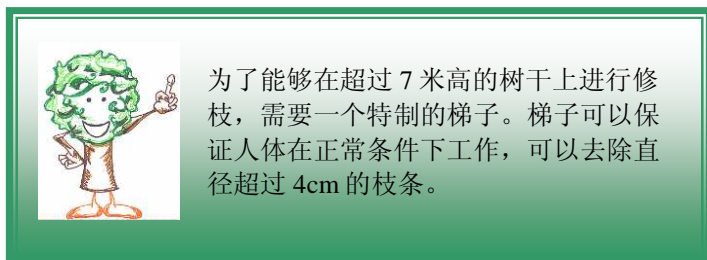
"迪斯泰 II"高空整枝梯子组的构成：

（1）梯子由 4 个单元组成，修枝高度可达 11 米。第一单元（基部）高 2.20 m 包含 8 个梯级，可以非常便利的接上其它 3 个组成单元（高 2.10 m 包含 8 个梯级）。

（2）安全带。

（3）钢制的固定元件及防脱带，确保梯子牢牢附在树体上。

（4）带有皮质保护套的高性能锯子。

操作步骤：

（1）将第一单元（基部）梯子架好，在此可操作范围内进行修枝作业。

（2）建议双手同时或者轮流使用锯子，这样可以避免臂力过快耗尽，以提高修枝质量。

（3）根据修枝高度进程的需要，利用连接元件将其它单元梯一个一个地连接并固定起来，以进行更高部位修枝。

图 17: 利用"DISTEL II"梯子系统对德国混农林系统中的樱桃木进行修枝

Ⓡ Relief cuts 1 and 2
Ⓕ Final pruning cut
--- Wrong pruning cuts

大枝条的正确修枝法：

- 注意不要把大枝下面的树皮撕掉！
  ➢ 对于较大枝条，第一步将枝条的前部去掉（如图蓝线部位），减轻枝条重量。接着将剩下部分去除（如图绿线部位）。
- 尽量减小修枝后枝茬的长度。
- 避免伤到枝条基部（注：平切）和留枝茬过长（注：中切）（如图红线部分）。

（注：右图中Ⓡ 预备切口 1 和 2；Ⓕ 最终切口；---为错误切口。）

优点：

(1) 高效。

(2) 符合人体工学要求。

(3) 修枝质量超高。

(4) 身体全面防护下的安全操作。

（5）可以修除更高部位的较大枝条。

3.3 Using loggers tape

Background:

After tree felling, the working process of de-branching and measuring the logs takes place. Marking the log length for cross-cutting takes about 1/5 of the total harvesting time. By combining the processes of de-branching and log measuring, the working time might decline.

Loggers tape is a metal tape of 15m, 20m or 25m length, wound up on a role, for length measurement of logs during the de-branching process. It can be fixed at forest workers belt. Several companies offer the loggers tape, the most recommended are

- J.A. Gadd Ltd. (UK)
- Stihl (Germany)

Components:

(1) Loggers tape
(2) Wax crayon (pen)

Procedure:

(1) Fix the loggers tape with its end (nail) at the butt end of the stem (Fig. 18)
(2) Move along the stem, from the butt end towards the crown, while cutting off The branches, either using a chainsaw or an axe (Fig. 19)
(3) Mark log length/ sections for cross-cutting with wax crayon
(4) Go ahead towards top end diameter
(5) Carefully rip the loggers tap to roll up the tape again
(6) Move to the next stem

Fig. 18: Fixing the loggers tape at the butt end of the stem (picture: Suchomel, 2010)

Fig. 19: Move along the stem while cutting off the branches (picture: Suchomel, 2010)

Advantages:

- High time efficiency
- Ergonomic working process
- Accurate measurement, even in difficult situations
- Safe movement (one free hand)

Fig 20: Loggers tape of J.A. Gadd Ltd.

3.3 伐木卷尺的使用

背景：

树木伐倒后，接着就是去枝和测量原木。为分段切割而进行的原木测量标记长度将耗费整个采伐收获过程的 1/5 时间。将去枝与测量标记原木的工序同时进行可以减少用工时间。

> **伐木卷尺**是一种金属卷尺，长度可分为 15m，20m 和 25m。在伐木去枝时候，可以同时使用伐木卷尺进行原木的测量与标记。可以挂在伐木工人的腰带上。有几家公司都在生产这种卷尺，推荐两家公司：
> - J.A. Gadd Ltd. （英国）
> - Stihl （德国）

工具组成：
（1）伐木卷尺
（2）蜡笔

步骤：
（1）将伐木卷尺的刻度前端的钉子固定在伐倒原木的基部（卷尺主体固定在工人腰间）。（如图 18）
（2）边用锯子或者斧头去除树枝，边从原木基部向树冠方向沿着树干移动。（如图 19）
（3）用蜡笔在原木上作长度或者节段标记以便锯开分段。
（4）一直向前直到最后直径处。
（5）从原木稍部向原木基部根据标记小心锯开各段，同时卷尺自动卷起。
（6）进行下一个原木分割工作。

图 18: 将伐木卷尺一端固定在原木基部
(picture: Suchomel, 2010)

图 19: 边去除树枝边沿着树干移动
(picture: Suchomel, 2010)

优点：
- 效率高。
- 符合人体工学。
- 测量精确，甚至在困难的条件下也能保证精度。
- 行走安全（可空出一只手自由活动）

图 20: J.A. Gadd Ltd.生产的伐木卷尺