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Conceptualizing the Convention on Biological Diversity:

Why is it difficult to determine the 'country of origin' of agricultural plant varieties?

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Seeds of change - Lessons to learn from implementing the CBD in the field of agroplant diversity

Sammendrag/Abstract
The Convention on Biological Diversity (CBD) comprises all components of biological diversity, including agricultural plant diversity. It is based on the sovereign right of states over their genetic resources, and sets out that the 'country of origin of genetic resources' is to decide with regard to access and benefit-sharing. It is also the preferred site for gene banks for these resources. The term is defined in the CBD as "the country which possesses those genetic resources in in-situ conditions". The essay discusses what this means with regard to agricultural plant varieties and concludes that for most varieties, it will not be possible to identify such a country. The discussion is based on two elements. First, the terms used in the CBD definition are singled out, defined and traced back to their semantic sources, in order to establish an understanding of what they mean with regard to agricultural plant diversity. Second, the findings are discussed on the background of evolution theories. The conclusion is that for most of our agricultural crops there will be no entity or party to decide over access, benefit-sharing or sites of gene banks, as they cannot be defined on the basis of the CBD. If properly implemented and without any modifications for agricultural plant varieties, the CBD will thus severely hamper the access to and management of agricultural plant genetic resources. However, there are negotiations going on. The International Undertaking on Plant Genetic Resources for Food and Agriculture has been under negotiation for almost a decade. It was initially thought of as a protocol to the CBD. However, the negotiating parties now seem to prefer it as an agreement under the FAO. Here a multilateral system for the management of agricultural diversity takes form, and will pertain to a list of plants. If the negotiators succeed in finalising this as a binding international agreement, the plants included in the list will be subject to a multilateral decision-making structure, whereas those not included will still be subject to the CBD. This may result in facilitated access and management of the listed plants whereas the genetic erosion of the remaining plants will continue. In rural societies based on traditional agricultural practices and varieties, this process may have comprehensive socio-economic consequences.

Stikkord/Key Words
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Conceptualising the Convention on Biological Diversity:

WHY IS IT DIFFICULT TO DETERMINE THE 'COUNTRY OF ORIGIN' OF AGRICULTURAL PLANT VARIETIES?

It is already almost impossible
to assemble meaningful information
on the origin and evolution of certain crops
as the evidence dims and fades away
with each passing year.

Jack R. Harlan, 1975

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Lysaker, October 2001

Regine Andersen

Contents

1 Introduction

It is now almost a decade since the Convention on Biological Diversity (CBD) was signed in Rio, and the time should be ripe to study its implementation. This is what I intended to do as I started work on my doctoral thesis in political science. As the Convention comprises all components of biological diversity, I decided to limit my scope to one that has received relatively little attention among analysts. I wanted to focus on plant genetic resources for food and agriculture (PGRFA).[1] However, it turned out to be anything but an easy task. My supervisor Cary Fowler pointed out how the division of labour between the CBD and the FAO's International Undertaking on PGRFA (IU) made it almost impossible to determine where responsibility for international regulation lay on this issue.[2] He also shared with me his observations on the fundamental problems in applying the provisions of the CBD on the management of PGRFA, as they seem to be designed largely with a view to undomesticated resources. In addition, I came to realise that the effects of the WTO Agreement on Trade Related Intellectual Property Rights (TRIPs) on the area was so comprehensive, that it would be impossible to analyse the effects of the CBD on the management of PGRFA separately. Finally, I had to redefine the analytic focus to make it fit with the emerging landscape of closely inter-linked and potentially conflicting international agreements pertaining to the management of PGRFA.

While this little story tells about the personal challenges involved in defining a PhD topic, it also gives more importantly an indication of the potential problems in applying the CBD on the management of PGRFA. The purpose of this report is to investigate one of these problems in greater depth, a problem that has so far only received marginal attention as compared to, e.g., the patent debate. The report is delimited to one of the basic principles of the CBD highlighted by Cary Fowler as difficult to apply on PGRFA (see also Fowler, 2001 forthcoming), i.e., the principle of 'country of origin of genetic resources'.

The CBD reaffirms the sovereign rights of states over their natural resources as an established principle of international law. On this basis it assigns to national governments the authority to determine access to genetic resources (Art. 15). Access is subject to prior informed consent of the provider country and the fair and equitable sharing of the benefits thereof on mutually agreed terms. Thus, it is the country that is providing access that is central also when it comes to the issue of benefit sharing. However, the Convention specifies that only Parties that are countries of origin of

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[1] Plant genetic resources for food and agriculture (PGRFA) encompass the diversity of genetic material in traditional varieties and modern cultivars, as well as crop wild relatives and other wild plant species that can be used as food, feed for domestic animals, fibre, clothing, shelter etc. (FAO, 1998: 1).

[2] Due to the Nairobi Final Act on the adoption of the CBD text (1992: Res. 3), outstanding issues pertaining to PGRFA gene bank accessions collected before the CBD and to farmers' rights were delegated to the FAO for further negotiations. As a result, the CBD was to cover PGRFA gene bank accession collected after the CBD and on-farm management of PGRFA, until the outstanding issues were solved. However, a large amount of the varieties in farmers' fields (under the CBD) have been collected for *ex situ* conservation prior to the CBD (under the FAO). In addition, it is difficult to distinguish between the varieties conserved prior to and after the CBD, due to the lack of standardised information systems. Finally, farmers' rights (under the FAO) pertain to their resources in the field (under the CBD).

genetic resources may provide access to such resources, or Parties that have acquired the resources in accordance with the CBD (Art. 15.3).

Gudrun Henne (1998:144) argues that the principle of country of origin of genetic resources represents a new form of access regulation to natural resources in international law, in that countries possessing genetic resources within their territory delegate this right to those that are countries of origin. As Henne shows, this may create problematic situations in cases where the country of origin and the source country are not identical (p. 142).

This is where our problem starts with regard to the topic of this exploration. Different components of biological diversity have different characteristics. One of the main characteristics of agricultural biodiversity is that it has evolved through the selection, use and exchange of seeds and plants by farmers over short and long distances since the dawn of agriculture – in addition to processes of natural selection. Thus, there is reason to assume that it would be hard to identify an exact point in time when a particular variety came into existence. Likewise, and partly because of that, there is reason to assume that it would be very difficult to determine the place or country where it should have happened.

If these assumptions are correct, it will, in most cases, not be possible to determine the countries that should be assigned the right to provide access to and share the benefits from the utilisation of agricultural plant varieties on the basis of the CBD provisions. Thus, again if the assumptions are right, they may indicate that the CBD is not conducive to the management of PGRFA. Management in this context refers to the conservation and sustainable use of PGRFA in line with the objectives and definitions of the CBD. If it is not possible to identify the country of origin of a genetic resource, it follows that providing access to it would also be impossible, provided that the CBD is to be followed. As genetic resources are living organisms, their use is the best guarantee for their maintenance. Thus, when access can not be provided, the use, and implicitly the maintenance of the resources, are hampered. Furthermore, equitable benefit sharing was aimed at providing incentives for the conservation and sustainable use of genetic resources, but when the country of origin can not be identified there is no party with which to share the benefits and subsequently no incentives in place.

Based on these considerations, the following proposition will form the point of departure for the analysis:

Proposition:
The principle of 'country of origin of genetic resources', on which central provisions of the CBD are based, is not conducive to the management of agricultural plant varieties.

The emphasis of this essay is on testing this proposition and providing an in-depth explanation of the results. However, it is also important to gain insight into the wider implications. Thus, the essay will conclude with a discussion on possible implications on the further formation and implementation of relevant international agreements.

In order to test the proposition, I will start by presenting the definition of 'country of origin' as provided in the CBD in the context of its overall objectives. The next step will be to explain how the terms used in this definition pertain to agricultural biodiversity, before identifying and discussing the theoretical contexts that may provide an understanding of what they mean in practise. As the definition stems from a biological context, it follows that biological theories, particularly evolution theories and theories on the origin of crops, will be central. However, also socio-economic approaches are relevant to an understanding of the dynamics behind the evolution of agricultural diversity. The text is thus based on a combined approach with a main emphasis on biology.[3]

2 How 'country of origin of genetic resources' is defined in the CBD and some words about the context

'Country of origin of genetic resources' is defined in the Convention (Art. 2) as '*the country which possesses those genetic resources in in-situ conditions*'. Two of the terms used in this definition are further clarified:

- 'Genetic resources' is understood as 'genetic material of actual or potential value'. 'Genetic material', in turn, refers to 'any material of plant, animal, microbial or other origin containing functional units of heredity'. There are no further specifications.
- 'In-situ conditions' is defined as 'conditions where genetic resources exist within ecosystems and natural habitats, and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties'. The term 'distinctive properties' is not defined in the Convention.

A distinction is made between 'country of origin of genetic resources' and 'country providing genetic resources'. The latter is defined as '*the country supplying genetic resources collected from* in-situ *sources, including populations of both wild and domesticated species, or taken from* ex-situ *sources, which may or may not have originated in that country*'. It is clearly stated that '*the genetic resources provided by a Contracting Party (...) are only those that are provided by Contracting Parties that are countries of origin or such resources or by Parties that have acquired the genetic resources in accordance with this Convention*' (Article 15.3). Thus, it is clear that 'country of origin of genetic resources' can not be understood as being synonymous with source country of such resources by any stretch of the imagination. It is the 'country of origin' and not the source country that is assigned the right to decide over access to genetic resources and to negotiate with regard to mutually agreed terms for benefit sharing related to access, provided they enact suitable legislation. It is also the 'country of origin' that is preferred as site for *ex-situ* conservation[4] (Preamble and Art. 9).

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[3] The report is based on an essay submitted to the NORAGRIC, The Agricultural University of Norway, as part of a doctoral course in development studies, where one of the main components was on the central biological fundaments of the PGRFA issue.

[4] '*Ex-situ* conservation' refers to '*the conservation of components of biological diversity outside their natural habitats*', where 'habitat' means '*the place or type of site where an organism or population*

It is important to consider this principle in the context of the overall objectives of the Convention (Art.1). These are the conservation of biological diversity, the sustainable use of its components, the fair and equitable sharing of the benefits arising out of their use, including the appropriate access to these resources and transfer of relevant technologies. We may infer that the Convention is based on the assumption that 'countries of origin of genetic resources' represents the adequate entities to decide over these matters. If this should not hold true with regard to certain components of biological diversity, it would infer the presence of a conflict between central provisions and the overall objectives pertaining to these components.

3 Understanding the terms used in the CBD definition on 'country of origin of genetic resources', as they pertain to agricultural biodiversity

The next task is to enhance our understanding of what the terms used in the CBD definition of 'country of origin of genetic resources' means with regard to agricultural plant genetic diversity in general and to agricultural plant varieties in particular.

3.1 Genetic resources

A key term, to which many of the provisions of the CBD pertain, is that of 'genetic resources'. What are the genetic resources of agricultural plant diversity that should be conserved, sustainably used, to which access should be facilitated and from which benefits should be shared? FAO has defined its work as comprising *plant genetic resources* for food and agriculture (PGRFA), a term that comprises domesticated[5] as well as undomesticated resources. *Plant genetic resources* is defined as the diversity of genetic material in traditional varieties and modern cultivars, as well as crop wild relatives and other wild plant species that can be used as food, feed for domestic animals, fibre, clothing, shelter etc. (FAO, 1998:1).

The main focus here is on domesticated plant varieties/cultivars. However, in order to understand what domesticated plant varieties/cultivars are, we should see them in the context of genetic resources. That means, taking the FAO definition as our point of departure, the context of the ecosystems surrounding them, together with their higher and lower taxa ('plant species' and 'genes'). We start with the whole, then go into the parts.

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naturally occurs' (Art. 2) For a more comprehensive introduction to the issue of ex situ conservation, see e.g. Rosendal (1995)

[5] *Domestication* stems from the Latin 'domus': house, dwelling, household, and means 'bringing into the household'. According to Harlan (1992:64), the term implies genetic changes that adapt the plant to the 'domus'. There are intermediate steps between wild and domesticated varieties. Harlan suggests a spectrum for the classification of varieties from wild over tolerated and encouraged to domesticated varieties. Full domestication would mean that the populations could not survive without man. In contrast, *Cultivation* is associated with human activities in caring for a plant, according to Harlan. We may thus understand domestication as the result of cultivation in combination with the interaction between the cultivated plant population and the natural environment, resulting in genetic adaptation.

Ecosystems

An ecosystem comprises the organisms living in a particular environment and the physical part of the environment that impinges on them (Wilson, 1992:396). The term was introduced by Sir Arthur Tansley in 1935, as a way to describe an organised unit of the environment. In Tansley's words, it encapsulates '*the idea of progress towards equilibrium, which is never, perhaps, completely attained, but to which approximation is made whenever the factors at work are constant and stable for a long enough period of time*' (Tansley, 1935, quoted in Odum, 1997:43). An ecosystem has all the components necessary for the function of its organisms, and their survival over the long term.

Regional units, either geographical or natural (e.g. an ocean or a grassland region), are called biomes (Odum, 1997:31). A region or biome may comprise several ecosystems. Ecologists distinguish between several types of biomes and ecosystems of the biosphere, (i.e., the parts of surface and atmosphere of the earth that are inhabited by living organisms: marine ecosystems, freshwater ecosystems, terrestrial biomes (e.g. temperate grassland, boreal coniferous forests, and evergreen tropical rain forests), and domesticated ecosystems (e.g. agroecosystems, plantation forests and agroforest systems) (Odum, 1997:248).

All domesticated agricultural plant varieties have once originated from terrestrial ecosystems and as long as the related ecosystems are intact, it is often possible to find their wild relatives there. However, due to the fast extinction of terrestrial ecosystems around the globe, the natural habitats of wild relatives to our agricultural plant varieties are disappearing rapidly.

When it comes to agroecosystems, there are great differences between them with regard to ecological equilibrium. Industrial agrosystems tend to have a high input of energy in the form of fertilisers and of pesticides. Rather than evolving towards equilibrium with the environment, these systems tend to combat their environments in order to attain the highest yields in the shortest possible time (Kellman and Tackaberry, 1997:234–267). Traditional farming systems are in general more adapted to the environment. They do not reach the same maximum yields as industrial agrosystems, but due to their adaptability to their local environments they tend to be more stable in the long run. One reason is that traditional farming systems normally are more diverse with regard to plant varieties than industrial agrosystems, and thus more genetically flexible (see the section on varieties and cultivars below). As a reaction to the environmentally negative effects of industrial agrosystems, the concept of integrated pest management (IPM) has been introduced in many parts of the world (Robinson, 1996:109). It still only comprises a fraction of the total area of industrial agriculture, but it has largely been recognised as successful and has a potential for wider diffusion.

Species

For a non-biologist, the meaning of the term 'species' might seem obvious at the first glance. There is a difference between apples and plums and between roses and lilies, so where is the problem? However, according to Mayr (1982:870), the number of species definitions in the biological literature is virtually unlimited. This is due to the enormous amount of variation within and between what we may label as species and the difficulties involved in drawing clear demarcations between higher and lower taxa (Mayr, 1982:252). One of the basic questions is how and to what extent groups of individuals must differ from each other to qualify for the term species. What are the characteristics that permit such an assignment? The history of the species discussion is long, and can not be dwelled on here. However, it is important to gain an impression of current status and its implications for agricultural biodiversity.

A definition that has found wide recognition is this (Mayr, 1992:273): ‘A species is a reproductive community of populations (reproductively isolated from others) that occupies a specific niche in nature.’ Different factors may determine niche occupation, such as species borders of competitors (Darwin), adaptation to a species-specific food niche (Lack), and adaptations that permit co-existence with potential competitors (all in Mayr, 1992:274–5). Niche occupation and reproductive isolation should be seen as two sides of the same coin, as the major biological significance of reproductive isolation is that it provides protection for the genetic constitution of an organism that is adapted for the utilisation of a specific niche. Thus, it is only when the criterion of reproductive isolations breaks down, that the criterion of niche occupation is applied (Mayr, 1992:275).

It is, however, not unproblematic to apply this definition on agricultural diversity. For the sake of simplicity we may infer that a species comprises such agricultural varieties and their wild relatives that can be interbred by traditional methods, and this may be sufficient for a range of plant types. However, for our oldest and most widespread cultivated plants, the definition does not help an understanding of their distinctions and interrelations. The wheat genus is a classical example. Already Darwin remarked that there is some doubt concerning the number of wheat species as they tended to be ranked as varieties (Darwin, 1868, Vol. 1:334). In the 1920s, Vavilov collected a huge amount of wheat samples from Europe, Asia and Africa, and found no less than six different species containing as many as twenty so-called subspecies among them – in addition to all the varieties (Vavilov, 1949/50:175–76). Harlan and deWet (1971, in Harlan, 1992:106–113) recommended as a solution to the problem abandoning all formal taxonomy in order to permit the use of an informal system used by those who work with cultivated plants professionally. The objective was to provide a genetic focus and a perspective on the genetic potentials for cultivated plants based on an informal categorisation of species into differentiated gene pools:

1. Primary Gene Pool that corresponds to the concept of biological species, as explained above.
2. Secondary Gene Pool that includes all biological species that will cross with the crop, where gene transfer is possible, but one must struggle with those barriers that separate biological species.
3. Tertiary Gene Pool that includes those species that can be crossed, but where gene transfers are impossible, or close to impossible, with traditional methods.

A hierarchy of subcategories is also suggested, comprising *inter alia* subspecies and races. However, there are no clear-cut definitions for these subcategories. The purpose is solely to provide a convenient division of categories, allowing for a reason-able amount of variation within each. The argument is that a classification of cultivated plants, given its enormous diversity and complexity, and the purpose of a classification, does not require further divisions.

Taxonomists could probably still spend much time on turf wars regarding these issues. However, a categorisation should have a purpose, and for the purpose of the use and management of PGRFA, Harlan and deWet's proposition seems fruitful.

Varieties and cultivars

Varieties and cultivars are the sub-populations of species and sub-species. But taxonomy does not get easier when it comes down to the parts. For wild plant populations, ecologists use the term 'ecotype'. An ecotype possesses certain characteristics suited to its own particular locality within the ecosystem and is genetically diverse as well as genetically flexible (Robinson, 1996:58). Genetic flexibility means that a population responds to selection pressures in that its genetic composition changes and it adapts. The flexibility is dependent on the variability of the genetic diversity within the varieties, because the different individuals need to have the reproductive advantage of the others in order to respond (Robinson, 1996:57–8).

For domesticated plants the picture is more complicated. Different terms are both used and confused. The terms 'race', 'variety' and 'cultivar' are often understood as more or less synonymous. Harlan even recommended avoiding the term 'variety' for this reason, replacing it with the term 'race' instead (1992:110). However, there are wide and important differences in genetic variability between the most ecotype-like varieties or races used by subsistence farmers and the distinct, stable and uniform ones produced by professional plant breeders. And there are many shades of difference between them. For the purpose of management, it is my opinion that we need good terms to mark these differences and their interrelations in order to understand the dynamics of PGRFA erosion and its effects, and to identify entry points for good management.

According to the Oxford English Dictionary (Hornby, 1974:969), 'variety' in biological terms means 'subdivision of a species'. We may thus use 'variety' as a common denominator for different categories pertaining to genetic characteristics. Based on Esquinas-Alcázar (1993:37), Zeven (1998), Fowler and Mooney (1990:xv) and Robinson (1996), I suggest the following figure for classification of agricultural plant varieties:

<table>
<tr><th colspan="5">CATEGORIES OF VARIETIES OF PGRFA</th></tr>
<tr><td>Ecotypes
(wild and
weedy forms)</td><td>Land races</td><td>Folk varieties</td><td>Creole varieties</td><td>Cultivars
(+ breeding lines
& genetic stocks)</td></tr>
<tr><td colspan="5">LEAST ⇐ Degree of:
Commercialisation
Genetic uniformity and stability
Genetic inflexibility ⇒ MOST</td></tr>
</table>

Ecotypes have been explained in the introduction to this section.

Land races are traditional local varieties that have evolved over centuries or millennia mainly due to natural selection, i.e., they are shaped by the *land*. They are specifically adapted to local conditions, tend to carry their names after the place they are grown, and possess large diversity within and between them (Robinson, 1996:182; Esquinas-Alcázar, 1993). Zeven (1998) describes them as varieties with a high capacity to tolerate biotic and abiotic stress, resulting in a high yield stability and an intermediate yield level under a low input agricultural system. Their local affiliation does not mean that their 'country of origin' is easy to determine. As we will see in the next chapter, land races exist as parts of dynamic systems that extend beyond a single place (Louette, 2000:110).

Folk varieties refers to varieties that have been developed by peoples through exchange and careful selection in an effort to cultivate attractive traits, in addition to the effects of natural selection. They tend to carry names that describe characteristic traits and qualities. There is reason to believe that folk varieties, due to their comparative qualitative advantages, tend to fare better in competition with modern cultivars in agricultural production than land races. However, thanks to extensive exchange practices over the centuries and millennia, the origins of these varieties may be even more difficult to trace to any particular place.

Creole varieties is a term originating from Latin America, describing varieties that are mixes of folk varieties and cultivars. Farmers recycle their folk varieties by adopting modern cultivars and re-selecting the best combinations from the old and new forms. The extent of this practice is difficult to determine, but there is reason to believe that such practices are spreading in developing countries. It goes without saying that tracing a country or countries of origin in such cases would be extremely problematic.

A *cultivar* (*culti*vated *var*iety) is usually bred after pure line principles (as discovered by Johansen, 1903) and the pedigree method as a clone or a hybrid variety, and it is genetically uniform (Robinson, 1996:414). Hence a cultivar normally meets the so-called D.U.S. criteria, i.e. criteria for genetic Distinctness, Uniformity and Stability, as defined by the International Union for the Protection of New Varieties of Plants (UPOV). Usually these criteria are applied in the national certification of seeds. If a plant variety is D.U.S. and satisfies the requirements of novelty, it can be subject to intellectual property rights protection after the criteria of UPOV (Kate and Laird, 1999:130). Cultivars have often very complicated pedigrees, indicating the problems it would involve in attempts to trace some country or countries of origin.

Breeding lines is the material developed by plant breeders as intermediate products in the process of producing a cultivar. They usually possess a narrow genetic base, as they are often developed on the basis of a small number of varieties or populations. *Genetic stocks* refer to other genetic combinations such as genic, chromosomal or genomic mutants also resulting from the process of developing a cultivar. This material can not be defined as varieties, but is included in this category due to its ties to the cultivar. Breeding lines and genetic stocks can be valuable for later breeding efforts, and are thus parts of the genetic diversity that is conserved *ex situ*.

As we might anticipate, there is a gradual change between the different categories of varieties. However, the distinctions are important in order to understand the level of diversity within the varieties. Although a cultivar may have a relatively broad genetic base, it is uniform and thus also genetically inflexible (Robinson, 1996:178). Cultivars are normally genetically disposed to give higher yields, but can not respond to selection pressures. The greatest genetic diversity and flexibility are among the varieties at the opposite end of the spectrum. These varieties are genetically disposed to give lower yields, but have high response to selection pressures.

Due to the fast expansion of modern agriculture, cultivars are increasingly dominating in fields. As a result, the access of traditional farmers to traditional varieties is decreasing, and it is not unusual for them to cross their traditional varieties with cultivars, thus paving the way for creole varieties. Although creole varieties might provide good alternatives for farmers, the consequence of the spread of such practices, is the further erosion of genetic diversity among and between the agricultural plant varieties in the fields, due to the increasing dominance of genes from a few genetically uniform varieties.

Genes

Genes are understood as units of inheritance, carried on chromosomes. They carry information pertaining to the heritability of particular traits, whereby an inherited trait may be controlled by a single gene, or by many genes. More specifically, genes have been described as sequences of base pairs in DNA molecules that contain information for the construction of protein molecules.

The molecular revolution has brought the understanding of heritability extremely fast forwards. However, the exact meaning and function of ‘gene’ is still not fully clarified. Traditionally, genes have been understood as static units that either did or did not exist in a particular DNA molecule. However, recent research has found that also genes, just as the organisms they are parts of, take part in the dynamics of change. Barbara McClintock found that genes tended to move between the chromosomes, and that such ‘jumps’ would determine the development of traits of the organism. She made this observation in the 1940s, but it was first recognised and confirmed by other scientists in the 1970s (Holdrege, 1999:78). Also the way in which proteins are built is a complex process, in which the role of genes has not been fully determined. Furthermore, a large fraction of the genes in the DNA molecule are never translated into proteins (Dawkins, 1976:47, in Dawkins 1982:156), leading biologists to the inference that they may not have any function, and thus labelling them as ‘junk genes’. Fischer came to the radical conclusion that genes as such do not exist in the static notion of the word, but that they are always in the process of transition. According to him, genes do not determine the tasks of the cell, but parts of the genes may be used for the production of proteins (Fischer, 1991 quoted in Holdrege, 1999:79). Several factors determine the dynamics and ‘behaviour’ of genes, e.g. it has been found that a gene can be turned on whenever its product is needed and then off again (Mayr, 1997:167). The driving forces behind this function and other dynamics of the genes have not been identified.

We could proceed with philosophising about the driving forces behind the dynamics of life, which are so vital and still so mysterious, and that, no doubt, would be an interesting exercise. For the purpose of this essay, however, what we need is a useful understanding of the term ‘gene’. For the sake of simplicity, we may conclude that a gene contains information on heredity, and that combinations of genes is one important determinant for the development of traits of an organism, or more specifically for our purpose, in a plant variety.

When it comes to the management of PGRFA, it is not only important to understand the function and dynamics of single genes (which is particularly important for the assessment of technologies pertaining to genetically modified organisms [GMOs]), but also how they are combined in the organism. A distinction is commonly made between the genotype and the phenotype of an organism. The genotype is the total genetic constitution of an organism, its genetic makeup, as opposed to its physical appearance. A phenotype is the totality of the characteristics of an individual, its observable properties. The genotype and the environment are important determinants in the development of the phenotype (based on Mayr, 1982:958–9, Rosenfield and Ziff, 1983:9). Plant breeders distinguish between crops with a narrow genetic base (e.g. many vegetables) and those that have a broad genetic base (e.g. many cereals). According to an inquiry carried out by Kate and Laird (1999: 142), there is a relatively much greater demand for new germplasm for the further development of crops with narrow genetic bases than for those with broad genetic bases. These results are important with regard to the regulation of access to genetic resources as well as to expectations pertaining to potential benefits to be shared. On this this backdrop, they may also have implications for the incentives for conservation and sustainable use of PGRFA.

Summing up

Agricultural plant varieties originated at some time in wild terrestrial ecosystems and have been cultivated ever since in agricultural ecosystems. They represent variations within species, and the diversity between and within varieties has developed since their domestication started. The properties of a variety are *inter alia* determined by its genetic constitution, and in traditional agriculture the genetic constitutions of varieties undergo continuous change. The crucial question with regard to the present concern is how a country of origin of an agricultural plant variety can be determined within this context. Should one seek to determine its origin according to the species to which it belongs? Should it rather be determined with regard to particular traits that are demanded, i.e. the origin of particular genetic compositions? Or should one seek to trace the evolution way back to the terrestrial ecosystem(s) from which it all once emerged? The only thing we know for sure is that there are no easy solutions to these questions. The authors of the CBD have tried to solve them with the help of the following distinctions.

3.2 ‘*In situ* conditions’ and ‘distinctive properties’

A ‘country of origin of genetic resources’ is, according to the CBD, the country which possesses those resources in *in-situ* conditions, which means in the surroundings where they have developed their distinctive properties. What is meant with ‘*in situ* conditions’ and ‘distinctive properties’ in this context?

‘In situ conditions’

The term ‘in situ’ refers to the site where particular populations of plants live in their natural habitats. The term has traditionally been used in the context of conservation efforts pertaining to undomesticated populations and natural ecosystems. In recent years it has also been applied in an agricultural context (FAO, 1998:51). Here it refers to the fields where crops are being grown.[6] However, when seeking to define this term more precisely in an agricultural context, problems arise. For wild plants, the term refers to their particular habitats. For crops, there is no such equivalent specification. Agricultural history tells us that agricultural practices have been spreading all over the world, over short and long distances, and so have their crops, for millennia. *In situ* is thus often implicitly understood as the place where a crop or variety evolved (Louette, 2000:109), an understanding that is given expression in the CBD definition.

Due to the continuous process of seed exchange between farmers over short and long distances and the natural genetic flow within and between farmers' fields (Louette, 2000:138), the place where a variety may have evolved may be hard to identify. It is difficult, not least, because the point in time at which the variety came in to existence may be hard to determine due to the continuous nature of evolution. These questions will be further explored in the next section and the next chapter.

Standing alone, the term '*in situ* conditions' gives no indication that is useful to the identification of a country of origin of PGRFA. The authors of the CBD sought to solve that problem with the specification that '*in situ* conditions' refer to the place where genetic resources had developed their 'distinctive properties'. Let us thus turn to the question of whether that helps us further in understanding the concept of 'country of origin'.

Distinctive properties

According to the same dictionary we availed ourselves of above (Hornby, 1974:254), 'distinctive' is an adjective that serves to mark a difference or make a distinction from something of a different kind, and 'property' refers to the special quality that belongs to something (p. 682). The first question we need to ask, is what this 'something' is. In the CBD definition it refers to genetic resources in general. For our purpose we can delimit this to domesticated PGRFA. As we have seen above, this may refer to species, as well as varieties and genes and the ecosystems surrounding them. However, it does not seem sensible to use the criteria of 'distinctive properties' for all these different categories. We can talk about different genes, but not about when or where they developed their distinctive properties. Likewise, we can differentiate between ecosystems, but it would not make sense to seek to identify their 'distinctive properties' in order to identify a country of origin. For species and varieties, though, it could make sense to use this term in order to seek to identify their country of origin. Species, as well as varieties, have different properties, and these properties distinguish

[6] The two main forms of conservation of agricultural varieties are *in situ* and *ex situ* conservation. *In situ* conservation refers to the growing of varieties in farmers' fields, whereas *ex situ* conservation pertains to gene bank storage. When plants are grown under traditional conditions, they are in the process of continuous genetic change in response to their environment, selection and further breeding. The varieties are thus not conserved as such, but the level of genetic diversity may be maintained and also further enhanced. In contrast, seeds stored *ex situ* are conserved with their genetic structures at a given point in time. Conservation is thus an appropriate term for *ex situ* storage of PGRFA, whereas management is a more adequate term when it comes to *in situ* conditions. The two forms can be understood as complementary in order to maintain genetic diversity.

them from one another. More specifically, we can say that the composition of common traits of a variety or species results in the properties that are particular to that variety or species. For species these properties can be expected to be distinctive as compared to other species, but, at the same time of a general nature, as they represent the common denominators for all the varieties within that species. For varieties, their distinctiveness is dependent on how their properties are defined. Their properties may be more or less distinctive as compared to other varieties, but 'variety' is the genus where the most detailed and precise properties can be identified.

On this basis, it could be argued that 'varieties' would be the most likely unit to use when determining a 'country of origin of genetic resources' under the CBD. After all, plant breeders do not seek access to species, but to particular varieties or traits, and conservation measures are usually also focused on varieties. On the other hand, most varieties that plant breeders use for the development of new varieties are cultivars, or the breeding lines and genetic stock on which they are based. These have not necessarily been developed in countries that have had anything to do with the development of genetic diversity for that crop. Thus, taking varieties as point of departure could undermine the whole intention with these provisions of the CBD.

Another possibility would be to trace the cultivars back to their native origins, i.e. the last generation of farmers' varieties before they were included in the breeding programme leading to the first cultivar, in order to determine their origins. For many crop cultivars these pedigrees are already quite complex, with ancestors in different countries, and the further the cultivars are improved, the more complex the picture will be. Simply examining the pedigree of any popular current rice cultivar confirms this assumption. As we see, the CBD offers no criteria that could enable us to understand the kind of distinctive properties that should be determined in order to identify the '*in situ* conditions' where they would have their origins.

Even if it were possible to establish the distinctive properties to look for, there would still be the problem of successive evolution in time. Different traits may have developed over time and slowly constituted the properties that are distinctive to a present variety or species in question. If it were possible to determine when a distinctive property took form, we would find several parents to one variety, which again have developed *their* traits based on *their* parents – and so forth. In theory, these developments could, for some varieties, be traced back to the dawn of agriculture. In practice, it could at best be possible to distinguish a few recent, distinctive turning points in the evolution of the various parent varieties, but for many crops the pedigrees would soon get too complicated.

Summing up

The term 'in situ conditions' does not make sense for agricultural plants if it is not further specified. The specification for agricultural plants in the CBD, juxtaposing it to the place where genetic resources developed their 'distinctive properties', helps us one little step further. Against this backdrop, we found that varieties and species represent the most likely taxa to take as point of departure for determining countries of origin of agricultural plant genetic resources.

However, this does not solve our problems of identifying '*in situ* conditions' and how it is possible to determine a country of origin for an agricultural plant variety within the context of different taxa (as addressed in the section on genetic resources above). Furthermore, the development of properties that are distinctive to a variety has often been a long and complex process, and it may thus often be difficult to identify the point in time or the place where that should have happened. This elaboration could not provide any answers to the questions. When seeking to understand these questions more in depth and detail, we need to take a dive into the theories of evolution and origin of cultivated plants.

4 Revisiting key theories on crop evolution and origin

What can we learn from the theories on evolution and crop origin that could help us further in our search for the countries of origins for agricultural plant genetic resources as referred to in the CBD? The basis for our current understanding of evolution was provided by Darwin and his theories will thus serve as a good point of departure for our investigations. In order to understand the fundaments of evolution, we also need a basic understanding of the most important laws of heredity, as provided by *inter alia* Mendel and Johannsen. The most important scientists searching after the geographic origin of agricultural plants in the twentieth century were Vavilov and Harlan. Their theories will be presented and discussed. Before summing up our findings, we will also take a brief look into the issue of socio-economic patterns of crop dispersal.

4.1 Darwin's theory of the origin of species

Charles Darwin was the first scientist to convincingly and comprehensively propose that all organisms descend from earlier forms of organisms that have been modified during the course of evolution (Darwin, 1859). Groups of similar organisms would descend from a common ancestor, and tracing this evolution could bring us to the origin of species. The most important factors determining the course of evolution were the variation in organisms and natural selection, i.e. that well-adapted organisms would propagate more, less adapted ones would tend to go under, and that offspring were able to reproduce themselves. In other words, natural selection was a result of differential reproduction. Through this form of selection, some traits would win through and others not. This would be decisive for the development of different varieties and for speciation.

In his efforts to untangle the mysteries of evolution, Darwin turned to domesticated animals and plants. Through studies of their domestication he found a key to an understanding of variability and change that could be transferred to the study of selection under natural conditions.

One of the problems he encountered when studying plants and animals under domestication was the successive links between varieties and between species and varieties. Although this finding was in harmony with his theory, it posed problems for the precision of his analysis. On the other hand, Darwin found that the evolution of domesticated plant varieties could at times take the form of jumps, but the difficulties with distinguishing between the varieties and between species and varieties remained.

This problem was also inherent in his analyses of natural selection, where he described varieties as forthcoming species (Darwin, 1859:48). The problem was, however, not inherent in the same complexity as for domesticated animals and plants. One of the particular characteristics of domesticated plants and animals, and an important reason for this complexity, was the intended crossings by people of different varieties over the generations in order to improve them (Darwin 1859:25).

Darwin proposed that a domesticated animal or plant would normally descend from one species. However, he was in doubt if that would apply to all. For dogs he suggested that there could have been more than one species (Darwin, 1859:14). He argued that his theory would imply that all varieties of a species that descended from one ancestor would geographically originate from the place where this ancestor had first emerged (Darwin 1859:258). Since then, they would have dispersed and evolved due to environmental factors and factors of inheritance.

In studying geological material and fossils, Darwin found that the process of evolution was extremely slow, although the pace differed somewhat from species to species. All in all, the whole process had endured through an inconceivable period of time, and he urged the reader who would not realise this to just shut his book (Darwin, 1859:229). He illustrated the point with historic data on domesticated plants. For instance, the farmers in the Neolithic period cultivated ten cereal plants, of which there were five kinds of wheat. Four of these kinds of wheat would be commonly looked upon as distinct species at Darwin's time (Darwin, 1868:335).

Although Darwin could not untangle the laws of heredity, his theory on evolution was revolutionary for biology and formed an important part of the basis for research that would revolutionise agriculture – for better and worse. Darwin has been blamed for the reductionism that formed the basis of modern agriculture, which has given rise to so many environmental problems in its wake, not least among them genetic erosion. However, Darwin's observations on the co-evolution of species and varieties can be used as a basis for ecological thinking just as they were once used to underpin reductionism. Thus, his theory should, perhaps, rather be regarded as germ to the paradox in natural science represented by these two basic paradigms. When it comes to the question of countries of origin of crops, Darwin's theories provide some important points:

- It would theoretically be possible to trace the origin of different varieties and species back to an ancestor and a certain place where this ancestor would have emerged for the first time.
- However, due to the successive character of the speciation process and the difficulties involved in distinguishing between species and varieties, it would be difficult to determine the point in time at which that should have happened.
- This be difficult due, not least, to the incredible time spans involved.

Thus, it would, based on Darwin, be theoretically possible to determine the country of origin of a variety or species, but extremely difficult to do with any measure of precision in practice.

4.2 Mendel's theories on heredity, Johannsen's pure lines and their aftermath

Gregor Johann Mendel contributed significantly to our understanding of evolution and to the science of crop breeding, through his great discoveries of the basic laws on heredity, published in 1866. His first discovery was that traits were passed on from parents via units of heredity to offspring following particular patterns. The individual units of heredity would not blend and could therefore be re-sorted in new combinations for each individual in the subsequent generations. The units of heredity would occur in pairs in the fertilised egg cell, containing one unit from each parent. The process would move from the combination of units of heredity into the new individual, and to the segregation of units of heredity for transmission from that individual to its offspring. The segregation would follow particular predictable patterns, decisive for the development of traits of the individuals from generation to generation. Mendel also found that each trait would segregate independently of the other traits (Volpe, 1977:23).

Mendel's discoveries created, when they were finally recognised in 1900, new potentials for heredity studies and formed a new basis of plant breeding. Most notably Johannsen's (1903) analysis of inheritance in populations and in pure lines brought developments a decisive step further. Johannsen found that self-pollinating plants could be bred in pure lines, by selecting – over a number of generations – the plants with the desired traits for reproduction by self-pollination. Through this process, the variation would decrease for each generation until it was not detectable any more. The result would be a genetically uniform plant and its breeds would be true to the genetic type. It is important to note that Johannsen recognised the works of the biometricians on population breeding and that he proposed that his theory had explanatory power also for their analyses (Johannsen 1903: 65). This is further underlined in the conclusion of his work, where he cites the wonderful verse of Goethe (Johannsen, 1903:67): '*Dich im Unendlichen zu finden – Musst unterscheiden und dann verbinden*': To find you in the infinite –separation is first required, then re-unification.

However, the pure line breeding won through and formed the basis of further developments in breeding methods. The pedigree method was developed to deal with the defects and weaknesses that emerged over time in pure lines. Carefully selected pure lines were crossed and often back-crossed, in order to develop the most attractive combination of traits. This method required access to genetic diversity and often resulted, in addition to the product itself, in surplus genetic material that could be used for breeding purposes at a later stage. In other words, it also produced diversity.

A similar method was developed for open-pollinated species, where inbred lines were produced after the pure line principles and then crossed. With single inbred lines the problem of inbreed deprivation would soon become immanent. When crossed, however, the first generation would have hybrid vigour, i.e. high yields. The next generation would already have reduced vigour. The technology pertaining to male sterility improved the method further.

The hybridisation methods have positive and negative effects. They are expensive in production, but under favourable environmental conditions, the expense is more than justified by the increased yields. Farmers using hybrid seeds have to buy new seeds on the market every year to keep up the yields, and have thus detach themselves from their own breeding technologies. For farmers who can afford the ‘entrance fee’, and have favourable environmental farming conditions, this is surely attractive. However, the socio-economic effects at local levels in developing countries are often complex as well as comprehensive.[7] The environmental implications are also immense, as the local genetic stocks are marginalized or eliminated and because hybrid seeds tend to need high input of fertilisers, pesticides etc, in order to compensate for their lack of resistance, due to the genetic inflexibility (Robinson, 1996), and to secure high yields. On the other hand, high yields are crucial to meet the world’s food demands, one of the most important arguments for this technology. A further implication of the hybridisation technology, is that it gave rise to the ‘commodification of seeds’ (Kloppenburg, 1988), providing plant breeders with a new form of market control and new potentials for profits.

Although these comments on Mendel and Johannsen and their effect helps us understand evolution, they do not bring us further in our search for the countries of origin of agricultural plants. What we do gain, however, are insights into the complexities of genetic resources, and how difficult it must be to determine the origin of particular distinct properties, i.e. traits, when tracing modern pedigrees. We also see some of the main challenges caused by modern agriculture, i.e., in its compensation for the lack of genetic variability with artificial input for growth and resistance, which, at the same time, marginalizes local agricultural genetic stocks, a process leading to genetic erosion and increased dependence on artificial input. Theories can have inconceivable implications.

4.3 The Vavilov theory on centres of origin of cultivated plants

The first person to pose the question of the geographic origin of cultivated plants was Alphonse de Candolle. He published his initial work on geographical botany in 1855. However, his most famous contribution is *Origin of Cultivated Plants*, published in 1882. Candolle introduced an interdisciplinary methodological approach including botany, geography, history, archaeology and philology. On this basis, he presented the first comprehensive overview of species with regard to their anticipated origin, early cultivation, and principal facts about their diffusion. Based on the evolutionary concepts of Darwin and taking the findings of Candolle as points of departure, the Russian scientist Nicolay Ivanovich Vavilov developed his hypotheses on the centres of origin of cultivated plants in the early 1920s.

Vavilov assumed that most of the main agricultural species could be traced back to one particular region, which would be its centre of origin. Furthermore, he assumed that these centres would be common for a range of crops, and that such regions could be universal centres of origin and of type formation, i.e. genetic diversification. Over the following two decades, he and his team members travelled around the world and collected and analysed an impressive amount of samples of cultivated plants in order to

[7] Such effects have been described and analysed by many scholars. One of the more detailed studies is the work by Else Skjønsberg (1989) on the changes that occurred in an African village after the introduction of hybrid corn seeds and the subsequent increase in cash crops production, leading to a fundamental socio-economic transformation of the whole society.

verify these hypotheses.[8] This comprehensive empirical work enabled him to develop his hypotheses as a theory.

One of Vavilov's first findings was that it was possible to distinguish between primary and secondary groups of cultivated plants (Vavilov, 1992:103). The primary crops were the basic ancient cultivated plants that were known to humanity only in their cultivated state (e.g. wheat, barley, rice, soybeans, flax and cotton). The secondary crops comprised all the plants that were derived from weeds that infested the primary crop fields, and were found to be useful on their own (e.g. rye, oats, false flax).

Another important finding was that closely related species often belonged to the same ecological groups. Vavilov compared the ecological peculiarities of a number of primary plants and the wild species known to be close to them and found that the closer the wild species or varieties were related to cultivated plants, the more often they belonged to similar ecological groups (Vavilov, 1992:118). These results, among others, paved the way to the realisation that closely related species often would have the same distribution area, and that it would be possible to trace their centres of origin.

His method was based on taxonomical phytogeography, as developed by himself, and on genetics and cytology. It had these main components (Vavilov, 1992:32, 146 and 321):

1. Differentiation of the plants studied into species and genetic groups.
2. Delimitation of the distribution areas of these plants, and, if possible, the distribution areas of these species in the remote past.
3. Detailed determination of the composition of the varieties and races of each species, and a general system of their inherited variability.
4. Establishment of the distribution of the inherited variability of the forms of a given species as far as regions and areas are concerned, and the establishment of geographical centres where these varieties are accumulated presently.
5. Establishment of the geographical centres of concentration of species that are genetically closely related.
6. Establishment of areas of diversity of wild species and varieties that are closely related to the species in question for the purpose of amendments.

The region of maximum variation, usually including endemic types and characteristics, could also be the centre of origin. The centres of origin would, as a rule, be characterised by many endemic variable traits and could comprise characteristics of entire genera (Vavilov, 1992:321). Within the centres of origin, Vavilov determined so-called foci of type formation of the most important cultivated plants (Vavilov, 1992:325), i.e. hearts of the centres with regard to genetic diversification and type formation.

Whereas Vavilov's principles were strengthened throughout the period of empirical investigations, the numbers and borders of the centres of origin of cultivated plants

[8] Vavilov was not allowed to leave the country after 1933, but his team members continued on the expeditions.

changed continuously. In the end, he suggested the following centres of origin of cultivated plants (Vavilov, 1992:429–433 and 1951:31):

VAVILOV'S CENTRES OF ORIGIN OF CULTIVATED PLANTS		
Centres of origin:	**Foci of type formation:**	**Some important crops:**
1. **The South-Asiatic tropical centre** (most of South and Southeast Asia)	The Indian focus The Indo-Chinese focus The island focus, comprising islands in Southeast-Asia	Rice, sugar cane, and a large number of tropical fruits and vegetable crops
2. **The East-Asiatic centre** (comprising East China, Taiwan, Korea and Japan)		Soybeans, different species of millet, the majority of vegetable crops and very many fruits
3. **South-western-Asiatic centre** (from Turkey to Kashmir)	The Caucasian focus The Asia Minor focus The North-western-Indian focus	Majority of endemic species of wheat, rye and fruits, pea, chickpea and lentil.
4. **Mediterranean centre** (Mediterranean countries)		Olives, carob tree, a multitude of vegetable and forage plants
5. **Abyssinian centre** (Highlands of Ethiopia, Eritrea, south-western parts of Arabia/Yemen)		Teff, Arabica coffee, sorghum, endemic species of wheat, barley and the enset banana
6. **Central American centre** (the northern parts and islands of Central America)	The mountainous South-Mexican focus The Central American focus The West Indian focus	Maize, several species of cotton, beans, gourds, cocoa, and probably sweet potatoes, yams, peppers and fruits
7. **Andean centre** (surroundings of the three foci in South America)	Andean focus proper Chiloan focus (southern parts) Bogotan focus (eastern Colombia)	Potatoes and other tuber-producing species, the quinine tree, the coca bush

It appeared that the centres of origin, as determined by Vavilov, corresponded with the ancient foci of agricultural civilisations (Vavilov, 1992: 156 and 434). However, he also found that, as a main tendency, agriculture must have developed from mountainous areas down to the valleys of the great civilisations rather than in the opposite direction as it had been thought. He explained this in that agriculture is much older than the great civilisations known to us (Vavilov, 1992:104 and 129). Vavilov's map has been described as an eloquent testimony to the co-evolution of crops and cultural Man (Harlan, 1975:183).

In addition to the theory of the centres of origin of cultivated plants, Vavilov introduced the concept of 'secondary centres of origin' for crops that had originated in primary centres but developed comprehensive genetic variants in other regions, which could be far away from the primary one (Harlan, 1975:183). For example, he found that the original common wheat species (with 42 chromosomes) was centred in the Hindu Kush and the western Himalayas, and also in Transcaucasia, whereas species with 28 chromosomes were concentrated in Abyssinia and in the Near East (Transcaucasia, Turkey and north-western Iran (Vavilov, 1951:45).

Vavilov's work brought crop science a huge step forward, and represents a pioneering work and a major contribution to our understanding of how our agricultural plants have developed from their very origins. He was in a continuous process of improving the map of the centres of origin up to his imprisonment and death, and nobody knows what the map would have looked like if he could have continued his work as he had planned.[9] Thus, whereas the basic principles of his theories seem to be valid for many crops, the location and borders of the centres may still be subject to discussion. The centres, as Vavilov determined them, appeared to be very large, and the main foci of diversity for different plants often widely distributed within these boarders. This could indicate a need for more precision. Also, empirical investigations after Vavilov's death have shown that there are potentials for corrections of the determination of centres of origin for single species (referred to in Harlan, 1975), and even for questioning whether all crops covered by his theories do have a centre of origin (see next section). Finally, when comparing his travels (Vavilov, 1997) with his centres of diversity, it appears that these areas largely coincide. All areas visited, except for some parts of the USA, the coast of Brazil, parts of Central Europe and Denmark, and a few areas in the (then) USSR that he also explored, were included in the map as centres of origin. Vavilov's expeditions were comprehensive, and his team members contributed significantly to the work. But enormous areas were not included in the investigations, such as Africa south and west of Abyssinia and Australia.

4.4 The Harlan theory on geographic patterns of crop variation

Since Vavilov, a range of people have brought greater detail to the picture with more precise determination of centres of origin for single crops. They have also questioned whether there is a centre of origin for all crops (e.g. Sinskaja, Fowler, Zhukovsky, Brücher, all referred to in Harlan, 1975:188–9). Jack R. Harlan has probably delivered the most comprehensive and fundamental contribution in this context.

Through a detailed study of a range of crops from different parts of the world, Harlan found that gene centres exist for some crops but not for all (Harlan: 1975:189). Several crops originated in the centres determined by Vavilov, but many originated elsewhere (Harlan, 1992:xii). Furthermore, he found that centres of diversity are not the same as centres of origin, and that there would be microcentres of diversity for different crops within the broader centres (Harlan, 1992:137 and 147). Thus, he described the emerging picture as '*one of mosaics over broad fronts rather than centres out of which all things come*' (Harlan, 1992:xiii). Each crop would be a case of its own, though with a certain consistency of evolutionary behaviour. There would be a basic mode of interaction between space, time, and genetic variability, where different crops showed

[9] Vavilov was imprisoned in 1940, following Stalin's persecution of leaders of agriculture and agricultural science. According to his son, he was sentenced to death because he would not publicly denounce his work. The execution was commuted to 20 years imprisonment. In prison he was starved to death. Vavilov died in 1943 (Vavilov, 1997:xxvii).

different geographic patterns of variation. On the basis of his empirical findings, Harlan proposed the following classification of crop species according to the interaction between space, time and genetic variation (1975 and 1992:137–140):

HARLAN'S CLASSIFICATION OF GEOGRAPHIC PATTERNS OF CROP VARIATION

Endemic crops:	Species that originated and have been cultivated in only one geographic area and did not spread appreciably (e.g. Guinea millet).
Semiendemic crops:	Species that have originated and been cultivated in definable geographic areas, with limited dispersal to other areas, possibly with some local nodes of high variability there (e.g. African rice).
Monocentric crops:	Species that originated from one identifiable geographic area, that were cultivated to crops in this area, and that have spread widely after that. Their centres of origin, as well as their centres of diversity are identical and well defined (e.g. arabica coffee).
Oligocentric crops:	Species with a definable centre of origin, wide dispersal and with several or many centres of diversity. They have developed nodes with high variability in different geographic areas (e.g. common wheat).
Noncentric crops:	Species that are cultivated over wide areas, with variations, but where no particular centre or centres of origin or diversity can be identified (e.g. sorghum).

Endemic and semiendemic crops would be relatively simple to distinguish, because they never spread very far and are *geographically restricted*. Monocentric crops would also be relatively simple to identify, because they are relatively new, i.e. *restricted in time*, and may thus be traced to their origins by historical data. The more difficult crops were, according to Harlan, the oligocentric and the noncentric crops. The oligocentric crops would be difficult to understand, as they are ancient and widely dispersed, i.e. growing in complexity through swathes of time and space. The noncentric crops would be difficult to understand, because they are derived from wild or primitively domesticated progenitors with a wide dispersal that would frequently involve multiple domestication (Harlan, 1975:189). Harlan proposed that, among others, pearl millet, sorghum and Asian rice could be examples of noncentric crops.

Harlan (1975:184) maintains that his classification has intermediate states and conditions, and thus limitations. Although such a categorisation is useful and important as an illustration for the different patterns of geographic variation, it may be difficult to apply when it comes to practical classification of crops. Domestication can take place everywhere where the environmental conditions are favourable, and the differences between the different categories may be difficult to get hold of. After having studied the origin of crops for a lifetime, Harlan states in his latest writings (1995:54) that due to the ambiguity of geographic patterns it is best to treat each crop separately and consider origin on an ecological basis. These well-founded doubts may serve as a reminder for those negotiators of international agreements, who may think that it is easy to determine the country of origin of crops.

4.5 Some words on socio-economic patterns of crop dispersal

Since the dawn of agriculture, seeds and crops have followed farmers and been exchanged between them over short and long distances. They have spread until they have met their environmental limits or were ousted by rival crops (Fowler and Mooney, 1990:38). Dispersal over long distances followed traders and explorers over land and sea. There was always an interest in new crops. Sumerians sent collectors to Asia Minor around 2500 B.C. in search of vines, figs and roses, and Queen Hatshepsut of Egypt sent an expedition to East Africa to collect incense trees in 1482 B.C. (Fowler 1994:4). These are only some few of many examples of wide distribution of crops in ancient time.

Since the rise of the Colombian Exchange,[10] the movements of germplasm reached a global dimension and a pace the world had never seen before. Ascending capitalism became a driving force in shaping this process (Kloppenburg, 1988:153). Europeans collected seeds and crops from the colonies extensively for selection, duplication and growing in other colonies with conducive environmental conditions. The Royal Botanical Gardens at Kew in England was the most important centre in a network of more than sixteen hundred botanical gardens in Europe (Fowler, 1994:6), and in the colonies new botanical gardens were established. Plantations expanded rapidly in the colonies in the second half of the nineteenth century and introduced new crops in areas where the old where displaced. However, this also created conditions for new diversity to emerge (Fowler and Mooney, 1990:41). In the twentieth century these actions slowed down, concentration on selected crops intensified and plant explorers rather searched in the Vavilov centres of diversity for new genes and traits for breeding programmes in order to improve the varieties in use (Fowler and Mooney, 1990:41). In the wake of the new breeding technologies and monocultures, the excessive dispersal of germplasm turned into a dramatic erosion of genetic resources.

4.6 What do we learn from the theories?

The theories discussed above have first and foremost provided us with insights into the complexities of crop evolution and the many hurdles and questions involved in any attempt to determine countries of origin. What we can say with relative assurance, is that there are some groups of agricultural plant species for which it may be possible to identify the country or countries of origin. These are the groups comprising what Harlan labelled endemic, semiendemic and monocentric crops. In any endeavour to determine the country of origin of a crop, Vavilov’s map of the centres of origin may be of great value, but not without the corrections of his successors in the field of phytogeography.

However, if we take varieties as point of departure for determining the country or countries of origin, only Harlan’s group of endemic crops would represent a relatively

[10] The term was introduced by A. W. Crosby in 1972, describing the trade emerging after Columbus brought the first seeds of the maize plant from the New World back to the Old World. Next year he brought wheat, olives, chickpeas, onions, radishes, sugar cane, and citrus fruits to support a colony. Following further expeditions and emerging colonisation, germplasm was exchanged between the two ‘worlds’. Maize, common bean, potatoes, squash, sweet potatoes, cassava and peanuts went east, whereas wheat, rye, oats and vegetables from the Old World went west (Kloppenburg, 1988:155).

clear case. For our oldest and most important domesticated plants, it would be nigh impossible to identify the countries of origin whether we focus on species or varieties. As we discussed in the previous chapter, the distinction between species and varieties is dim, particularly when it comes to the search for geographic origins. And the variety approach can not help us over this hurdle. Harlan labelled these oldest and most important domesticated plants oligocentric and noncentric crops whereas Vavilov referred to them as mainly belonging to the primary group of cultivated plants. Both found it most problematic to find a way to trace these crops back to their precise origins.

5 Conclusions and consequences

Based on the above, some conclusions can be drawn with regard to the proposition presented in the introduction to this essay. These conclusions will form the staring point for a discussion on potential consequences with regard to future formation and implementation of relevant international agreements.

5.1 Conclusions with regard to the proposition

In the introduction to this essay, I proposed that the principle of 'country of origin of genetic resources', on which central provisions of the CBD are based, is not conducive to the management of agricultural plant varieties. Is that right?

After having discussed definitions and theoretical frameworks of relevance to the problem, I think we can conclude that the picture is not black and white, but rather one of different shades. Some are almost black, some are dark grey and a few, rather small area are almost white.

With regard to species, there are some few crops, which are clearly endemic, semiendemic or monocentric, and that can be traced back to their places of origin with a rather high degree of certainty. However, by and large, these do not belong to the most important food crops of the world. For a range of other crops, it is theoretically possible to identify their geographic origin, but in practice close to impossible. For some crops there is most likely no such thing as a country or countries of origin. They have entered into domestication at various places in the world, and trying to highlight one or a few would make no sense. Thus, for most crops, including the most important food crops, it is not worthwhile trying to identify a country of origin, as the results, if any, would be too uncertain.

The picture does not change much if we turn to varieties due to the difficulties involved in distinguishing between varieties, and between varieties and species. When tracing the evolution of varieties back in time, we mostly find that they developed through many stages and often at different places. Thus, the variety approach does not make it easier to determine the 'countries of origin of genetic resources'. Only in cases where entire genera are to be found endemic in one country, may we be able to say with some degree of certainty that this is the one and only country of origin.

The CBD does not help us further in answering these questions, as it does not provide a clear answer as to what exactly 'origin' refers to. It could be species, varieties, traits or even genes. And these may have emerged at very different places in the world.

Even if the CBD could provide a clear answer, the nature of successive evolution would make it difficult to determine the point in time – and thereby also the place where the particular resource originated.

For most of our agricultural crops and their varieties, there will be no entity or party to decide over access, benefit sharing or site of gene banks, as they can not be defined on the basis of the CBD. If properly implemented, this will severely hamper the access to and management of agricultural plant genetic resources, as anticipated in the introduction.

In this context it might help to remind the reader that the CBD and its provisions based on the concept of 'country of origin' may very well be useful in the management of wild plant genetic resources. Here it is common to distinguish between endemic and non-endemic species, but also the non-endemic species have local eco-types, it is thus possible to identify one or a few countries of origin in most cases. It follows, that 'source country' and 'country of origin' are mostly identical for these components of biodiversity.

The problem with the CBD is, then, that it applies to all components of biological diversity, without sufficiently distinguishing between the different characters and management needs, and without making clear how the principle of state sovereignty over the components of genetic diversity can be exercised. The only difference that is made for PGRFA pertains to genetic material collected in gene banks before the Convention entered into force. According to the Nairobi Final Act on the adoption of the CBD text, this is an outstanding issue, and these resources are thus yet not covered by the Convention. The problems related to this are pointed out in footnote 2.

5.2 Illustrating the problem: An odyssey in rice

So what does this mean in practice? The following story about two varieties of rice which both travelled far and wide may illustrate the problem. It shows how genetic resources have been shared and disseminated from one part of the globe to another, while evolving slowly and more or less successively. What would we do if we were given the task of determining the country of origin of these varieties in line with the CBD?

A GENETIC ODYSSEY IN RICE (based on Hargrove 1999)

In 1982 a rice breeder from Colombia visited Tarapoto in Peru's upper Amazon Basin. He found that subsistence farmers there grew some good rice varieties, which they called Carolino. After thorough investigations, it turned out that the rice had stemmed from South Carolina a long time ago where it was called Carolina Gold and Carolina White. It was probably brought to Brazil by war veterans who migrated from South Carolina after the Civil War in the 1860s. From there it spread around the Amazon basin.

> But how did the rice arrive in South Carolina? In the late 1680s a ship sailing from Madagascar to New York was forced by a storm to dock in the harbour of Charleston. The captain gave about five kilograms of rice to a local botanist in the town before he left. The rice thrived and became the sister varieties Carolina Gold and Carolina White. Slaves from West Africa, who knew about rice cultivation from their homes, contributed the technological know-how, and the rice varieties spread and became popular in South Carolina.
>
> However, the rice varieties from Madagascar did not start their journey there. Rice was introduced to Madagascar by Indonesian immigrants in the 1st century A.D. We may thus assume that the rice found in Peru originally came from Indonesia, and that it had been disseminating, changing its traits slowly and successively as it did so to its present varieties, for about 2000 years – at least.

Now, the place of origin of these two varieties could be said to be in the place were they were grown (the Amazon) or where they were refined to become the sister varieties Carolina White and Gold (South Carolina). However, it could also be said to be in the country where they had thrived most of the time (Madagascar), which was likely also a decisive place for the development of their traits. Finally, the origin could be said to be where they probably originally came from (Indonesia). Or did they originate there? Alternatively, one could dismiss the variety approach and seek to identify the countries of origin of Asian rice, and for sure, many people have tried that already.

What sense would it make to use time and scarce resources to seek to unravel such extremely complicated issues of origin? And who should be the arbiters in this effort: scientists or negotiators? Would it help to halt the erosion of agricultural plant genetic resources, or would it in any way help to improve the urgently needed management of these resources?

The whole problem seems to be based on a fundamental misunderstanding, namely that the concept of ‘country of origin of genetic resources’ can be applied for agricultural plants. As this is only possible in very few cases, the provisions based on this principle are misleading, and thus – when it comes to PGRFA – in conflict with the overall objectives of the CBD.

5.3 Implications for other relevant international agreements

These conclusions are not only important for the implementation of the CBD. They may have implications for the whole constellation of regimes pertaining to the management of PGRFA. There are three regimes that are overlapping in this regard: the CBD, the IU and the TRIPs.

The International Undertaking on PGRFA is a non-binding agreement under the United Nations Food and Agriculture Organisation (FAO), pertaining exclusively to genetic resources related to agriculture. The objectives are the conservation and sustainable use of PGRFA for future food security and the fair and equitable sharing of the benefits arising out of their use. It is the oldest of the three agreements and was first adopted in 1983, with revisions in 1989 and 1991.

Since the mid-nineties, it has been under re-negotiation, with the purpose of harmonising it with the CBD and making it a binding agreement either under the FAO or as a protocol to the CBD. A text was adopted on the Sixth Extraordinary Session of the Commission on Genetic Resources for Food and Agriculture (CGRFA) under the FAO in June 2001. However, several important issues were not solved in the text, and were thus left in brackets. At the time of printing of this report, the text has been forwarded to the Director General of the FAO for final approval at the FAO Conference in November 2001, but the important issues have so far not been solved (Andersen, 2001).

Harmonising the IU with the CBD has not been an easy task, not least due to way in which the sovereignty principle has been translated into the principle of 'countries of origin of genetic resources'. In seeking to solve the problems this approach represents with regard to PGRFA, the negotiators have agreed on a multilateral system of access and benefit sharing for selected crops, to which the states collectively delegate their responsibilities. However, the parties seem to have great difficulties to agree on a list of crops for the multilateral system. The criteria should be that the crops are important for food security and that there is interdependence between the countries pertaining to the utilisation of the crop genetic resources. However, there are deep-running controversies with regard to a range of crops and how to apply the criteria.

The questions and considerations posed in this essay are relevant to the finalisation of the IU and for the implementation of the CBD for the following reasons:

1. If the IU is adopted as a legally binding international agreement, it will apply to a list of crops agreed to by the parties. The rest of the crops will be subject to regulation directly under the provisions of the CBD, or – for genetic resources collected in gene banks before the Convention entered into force– remain outside international regulation. If the provisions of the CBD are followed, the effects for the resources that are not on the list of the Multilateral System will most likely be detrimental to the intention of the Convention. The most realistic scenario is, however, that the CBD is not followed in this regard. That would in practice mean that the resources would be without a legal international regulation.

2. If the IU is not adopted as a legally binding international agreement, there are two possibilities. The 1991 version of the IU is still in force as a non-binding agreement, and may continue to be so, or it may be revised as a further non-binding agreement, but probably without the Multilateral System, as that would require a broad and legally binding consensus. In both cases the CBD will take precedence with regard to all PGRFA that has not been collected in gene banks before 1993. From a legal angle, the CBD would have to be applied also when this is not conducive to the implementation of the non-binding IU. However, there would be great difficulties in determining whether the CBD would apply to different kinds of PGRFA, due to difficulties in differentiating between gene bank accessions collected before and after 1993 and those growing *in situ* (see footnote 2).

3. While we are waiting for a revised IU, the CBD is being domestically implemented around the world. The result might be that regulations are introduced that are not conducive to a later implementation of a legally binding IU. One of the symptoms of

such a tendency is that access to PGRFA has become more restricted in countries that have introduced a CBD based legislation.

4. The CBD implementation in developing countries is attracting financial support from multilateral, bilateral and non-governmental aid agencies. However, these efforts are almost entirely geared towards the wild components of biological diversity. Due to the division of labour between the CBD and the FAO and to the extremely delayed negotiations of the IU, there is little acceptance for supporting efforts aimed at the management of PGRFA with reference to the CBD.

What is certain of is that world has not yet managed to adopt a legally binding international agreement that is conducive to the conservation and sustainable use of PGRFA, and that these resources are disappearing without any intervention by the international community. However, there is one more aspect that is important in this picture, and that relates to the consequences of the implementation of the TRIPs.

The Agreement on Trade-Related Intellectual Property Rights (TRIPs) under the World Trade Organisation (WTO) is one of the central pillars of the WTO. It came into effect in 1995 and provides minimum standards for the protection of intellectual property rights in the member states. In this context, the WTO members are allowed to exclude plants and animals other than micro organisms, and, essentially, biological processes for the production of these from patentability. However, members shall provide for the protection of plant varieties 'either by patents or by an effective '*sui generis*' system or any combination thereof' (article 27.3b). This article pertains to *inter alia* PGRFA.

In general we may say that patents on genetic resources restrict access to them. The extent to which they do so is dependent on their coverage, i.e. whether they apply to a product like an improved variety or a process that may include the breeding lines of varieties used for that purpose. The CBD states that patents and other intellectual property rights may influence the implementation of the CBD, and thus obliges the parties to co-operate in order to ensure that such rights are supportive of and do not run counter to its objectives (article 16.5). On the other hand, it maintains that access and transfer of genetic resources shall be provided on terms that are consistent with the adequate and effective protection of intellectual property rights (Article 16.2). There are thus different opinions on whether there is a conflict between the CBD and the TRIPs. Under these circumstances the practice is rapidly emerging that patents on PGRFA are applied for and granted. The negotiators of the IU have tried to solve this problem by imposing provisions that delimit the possibilities to procure patents on PGRFA that is accessed under the Multilateral System, or, as a minimum, to make sure that benefits can be derived from such patents for the maintenance of PGRFA. There is hence a potential for continued access to these forms of PGRFA. However, those resources that are not covered by the multilateral system are not covered by an effective international regulation and may thus become subject to patents and subsequently to limited or severely limited access. As the best guarantee for the maintenance of PGRFA is their use, patents thus represent a threat to their further existence.

We may conclude that the management situation for PGRFA is deteriorating rather than improving as a consequence of the attempts to set up an international management regime. Food crop varieties are lost forever. In a long-term perspective the consequence is the steady decrease of genetic potentials that could solve future agricultural problems and meet future food demand. In a short-term perspective the situation for small-scale traditional farmers in developing countries is deteriorating in response to the loss of traditional varieties. In rural societies based on traditional agricultural practices, this process may have comprehensive socio-economic consequences.

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