Quesungual & Kuxur Rum: Ancestral agroforestry systems in the Dry Corridor of Central America

Maize growing on a hillside Quesungual field

Overview of practice

The Central American agroforestry systems Quesungual (QS) and Kuxur Rum (KR) integrate basic grain crop production – mainly maize, common bean and sorghum – with multi-purpose trees. A permanent soil cover with biomass enhances erosion protection, soil fertility and soil moisture retention, especially on susceptible hillsides. In contrast to slash-and-burn cultivation, no burning is applied to clear plots for crop cultivation.

GLOBAL ALLIANCE FOR CLIMATE-SMART AGRICULTURE

Food and Agriculture Organization of the United Nations

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KEY MESSAGES

1. QS & KR improve the natural resource base and yields of smallholder basic grain production – mainly maize, common bean and sorghum in Central America.
2. QS & KR increase the resilience of smallholder farmer livelihoods to climate variability.
3. QS & KR provide a viable replacement for slash-and-burn cultivation and reduce greenhouse gas emissions.
4. QS & KR improve and diversify smallholder livelihoods by providing fruit, fire and construction wood.

Overview of Quesungual & Kuxur rum (QS & KR)

Quesungual[1] (QS) and Kuxur Rum[2] (KR), originated as a local adaptation of QS, are both agroforestry systems that have developed as alternatives to the common practice of slash-and-burn agriculture in hilly areas of the Dry Corridor of Central America, in Honduras and Guatemala respectively. Based on ancestral knowledge and enhanced by modern scientific knowledge, both systems integrate the production of basic grain crops, mainly maize, common bean and sorghum, with multipurpose trees. Usually two crops per year are grown in association[3] and production practices typically used in the region are improved by the use of minimum tillage for minimum soil disturbance, mulching to obtain permanent cover of the soil surface (see FIGURE 1), and, ideally, by use of improved local seed varieties.

FIGURE 1: Farmers using planting sticks to sow maize on a Quesungual plot covered with mulches (Intibucá, Honduras). Copyright: FAO/Suyapa Maradiaga

QS & KR are ideally established on plots that form part of a rotation under slash-and-burn cultivation and have lain fallow for several years (secondary forest). The plots are manually cleared of vegetation and cuttings are shredded and distributed on the soil surface as mulch. These mulches decompose and are incorporated in the soil over time to build up the soil organic matter. In the case of KR, tree rows of *Gliricidia sepium*, a nitrogen (N)-fixing species, are established along contour lines by striking, using cuttings from the plot clearing, and retaining and integrating trees from natural regeneration in the tree rows. In the case of QS, selected trees and shrubs from natural regeneration of the fallow are retained scattered across the plot and pruned to allow sufficient light for staple crop production. According to site and farmers' preferences, additional fruit and timber trees are planted. Commonly used species include *Byrsonima crassifolia*, *Psidium guajava*, *Citrus* spp., *Persea americana*, *Mangifera indica*, *Carica papaya*, *Anacardium occidentalis* (for fruit); *and Cordia alliodora*, *Diphysa robinoides*, *Swietenia* spp., *Simarouba glauca*, and *Cedrela odorata* (for timber). Tree density is usually between 70 and 150 dispersed trees per hectare from natural regeneration in QS and around 600 trees per hectare in KR, while crown cover should not exceed 25% (FAO, 2005; Hellin *et al*., 1999; MARN, 2009; CATIE, 2017).

Benefits of QS & KR

Reduced surface runoff and erosion: The permanent soil cover with organic mulches – derived from tree pruning and crop residues – enhances water infiltration at the soil surface and leads to reduced surface runoff and erosion and, thus, reduced loss of fertile topsoil and nutrients (CATIE, 2017). This is particularly relevant as the Dry Corridor area frequently experiences high-intensity rainfall

FIGURE 2: Soil erosion on degraded slopes in a typical hilly landscape of the Central American Dry Corridor dominated by slash-and-burn cultivation (Yoro, Honduras). Copyright: FAO/Julián Carrazón

[1] Quesungaul is the name of the Honduran village where the ancestral agroforestry practice was discovered.
[2] 'Kuxur rum' means 'my humid land' in Ch'orti', the local language of the Guatemalan region where the practice was developed.
[3] Mostly relay cropping where the second crop, e.g. beans, is planted between the rows of the mature first crop, e.g. maize. Traditionally, in Mesoamerica, three crops were grown in association: maize, beans and squash. Since the introduction and promotion of mineral fertilizers, agro-chemicals and commercial seed in the 1960s, slash-and-burn agriculture had degenerated into a presumably more efficient maize monoculture.

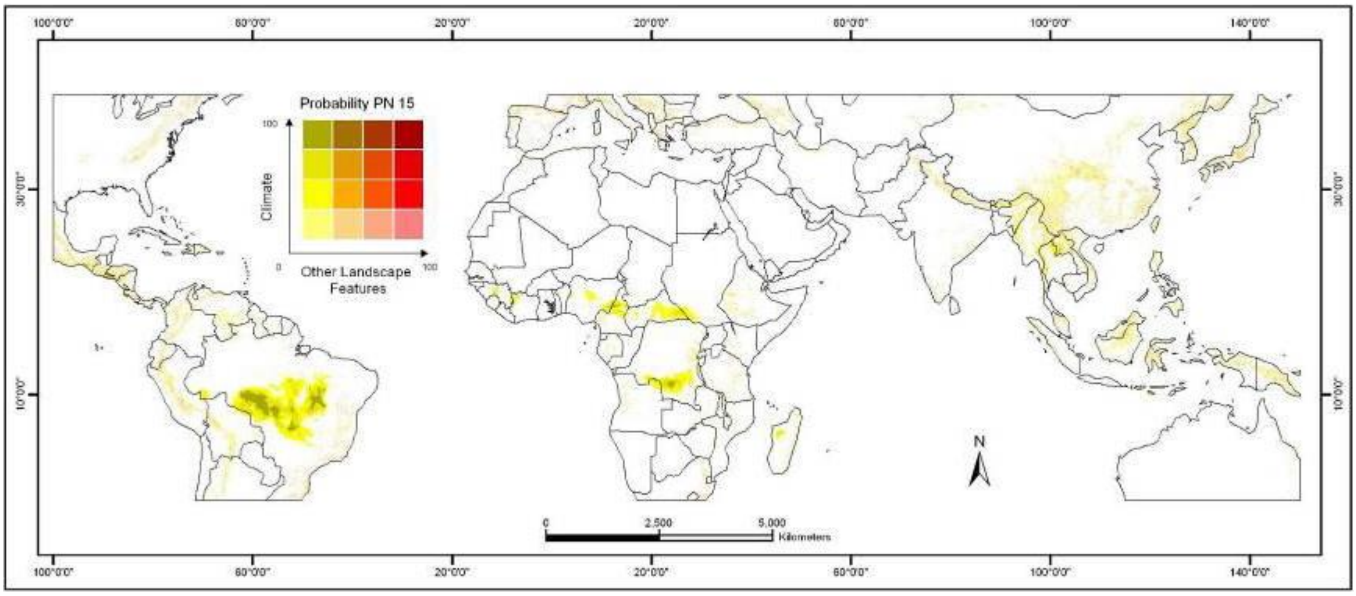

FIGURE 3: Pan tropical map showing potentially suitable areas for the adoption of Quesungual agroforestry system (Source: CIAT, 2009).

events during the rainy season (see FIGURE 2).

Increased resilience to drought: The tree root system, permanent soil cover, and increased soil organic matter enable QS & KR to infiltrate, retain and conserve larger quantities of water over longer periods of time in the soil. This stabilizes yields despite prolonged droughts (FAO, 2005 and 2010).

Reduced greenhouse gas (GHG) emissions and improved carbon capture: GHG emissions are avoided by abandoning the practice of burning for clearing forest plots before cultivation. In addition, QS & KR present higher levels of above- and below-ground biomass and soil organic matter and hence hold potential for long-term carbon sequestration in soils.

Extended cultivation period: QS & KR are rotational systems where each plot is used for crop cultivation for a limited period of time and successively left fallow to fully restore soil fertility. Compared with slash-and-burn, QS & KR plots can be cultivated for an extended period of time and with greater productivity (Hellin *et al*., 1999; CATIE, 2017).

Diversified and improved livelihoods: Tree products supplied by the agroforestry systems, like fruit, timber and firewood, can reduce household expenditure or constitute an additional source of income for smallholder farmers. Income generated from the sale of yield surplus and land resources freed up by longer cultivation cycles can be dedicated to the introduction of new market-oriented crops or husbandry (FAO, 2010; CIAT, 2009).

Challenges to adoption of QS & KR

The development and successful adoption of QS in Honduras occurred against the backdrop of low-performing and unsustainable rain-fed subsistence agriculture. These cropping systems were already experiencing low to moderate levels of soil degradation – in part caused by the use of slash-and-burn practices – and increasingly erratic rainfalls, and the need for the identification of alternative production practices was evident.

Factors that facilitated its success and adoption were: it was built on practices already known by local farmers and integrated their traditional knowledge e.g. about pest control and tree species that sustain intensive pollarding (Miguel Ayarza and Ian Cherrett in UNEP 2016); improved access of farmers to markets for farming inputs and sale of production surplus; better understanding of the ensemble of promoted techniques; and collective action and commitment of the communities.

Land ownership is another important factor for the adoption of QS. The first adopters in an area were usually owners of small landholdings. Farmers cultivating rented land often lack motivation to invest labour in improving the cropping system, as they may not be benefitting from their efforts in the future or are even obliged by landowners to use the slash-and-burn system. This barrier can be overcome by regulations requiring tenant farmers to maintain the share of forest and permanent cover without burning on their rented plot, as experiences from Honduras and from Guatemala show (Ayarza and Welchez, 2004).

In Nicaragua, adoption through farmer-to-farmer extension was very successful. Payments for environmental services could provide an additional incentive to promote the adoption of QS (CIAT 2010).

For the introduction of QS or KR to new locations, it is important to allow for a participatory process among local communities to adapt the practices in a way to respond to location-specific needs and to increase their acceptance (CIAT, 2009; Ayarza *et al*., 2010).

Where can QS & KR be practiced?

QS & KR evolved and are promoted in the Dry Corridor of Central America in areas characterized by tropical dry forest with distinct dry and rainy season, a bimodal rainfall pattern in the rainy season, average annual rainfall between 500 and 1400 mm and average annual temperature in the range of 17 to 25 °C (CIAT, 2009; FAO, 2010). The area under QS in the border region of Honduras and El Salvador is estimated to over 3000 square kilometres (Luis E. Álvarez Welchez, pers. comm.). The systems are most suitable for small landholdings (up to 5 ha) and were conceived to control erosion, stabilize yields and improve food security in communities on hillside locations at altitudes between 200 and 900 m a.s.l. with relatively poor, stony, unconsolidated soils where QS & KR provide the greatest benefits. But also in level areas they can serve as an important means for soil water management in smallholder agriculture. The probability map in FIGURE 3 identifies areas across the globe that potentially provide similar climatic and socio-economic conditions as in existing QS sites in Central America, including areas in Central America, South America, South-East Asia, and Sub-Saharan Africa (CIAT, 2009).

Contribution to CSA pillars:

How do QS & KR increase productivity, farm livelihoods and food security?

The soils on hillsides in the Dry Corridor are generally shallow, stony and of low fertility. QS & KR enhance the nutrient retention and cycling in the agroecosystem through the practice of mulching, in particular with N-fixing tree species. While under slash-and-burn cultivation soils are exhausted after three to four harvests and plots return to fallow, the increase in soil fertility under QS & KR allows each plot to be cultivated for a period of more than ten years, if properly managed, while delivering increased yields at the plot level (see e.g. TABLE 1).

TABLE 1: Yield development of maize and common bean over nine years (1993 to 2001) after switching from slash-and-burn cultivation to Quesungual agroforestry system in Honduras. (After: FAO, 2010)

Staple crop	Yield (t/ha)		Increase
	Year 1993	Year 2001	
Maize	1.23	2.73	122%
Common bean	0.26	0.78	200%

At the level of the entire farm, QS & KR increase land productivity due to the extended cultivation period of single plots and the reduced area of fallows. It is estimated that on 1.4 ha of land under QS & KR (assuming ten years of cultivation and five years of fallow) a farm household can satisfy its annual requirements of basic grains, compared to 5.6 ha under slash-and-burn cultivation (assuming two years of cultivation and 14 years of fallow) (FAO, 2010). This increased land productivity enhances the provision of basic grains for smallholder households, reduces the production risk and improves their food security. Potential yield surplus can be sold on the market to generate income as well as tree products from the QS & KR plots, such as fruit and timber. In order to capitalize on the increased yields, it is important to ensure that appropriate grain storage facilities are in place that allow farmers to sell surplus when prices are favourable. The trees can also provide forage for livestock and firewood for household consumption. Despite the relatively high labour requirement for the establishment of plots, QS & KR also require less labour on average (CIAT, 2009; FAO, 2010).

How do QS & KR help adapt to and increase resilience to climate change impacts?

The Dry Corridor of Central America is regularly exposed to extreme weather events, generated by the El Niño Southern Oscillation (ENSO) and associated droughts as well as heavy rains associated with intense depressions including hurricanes. Frequency and intensity of such events are expected to increase with climate change. QS & KR can drastically reduce the impacts of high-intensity rainfall events. The permanent soil cover results in increased water infiltration into the soils (e.g. up to 29 percent in the rainy season under QS in Lempira, Honduras; CIAT, 2009) and provides protection of the soil surface, thereby reducing the generation of surface runoff and the erosion of soil (by 92 percent each; CATIE, 2017). The improvements of soil quality under QS & KR in terms of organic matter content and porosity lead to a higher water retention capacity. This in combination with higher infiltration rates allows to reach higher soil moisture levels which increases the resilience to prolonged dry spells and drought. Observations from Lempira, Honduras, showed an increase of gravimetric soil water content (U) in the dry season from 8% to 29% over a period of eight years, i.e. an increase of soil water by 263% (FAO, 2010). Similarly, soil moisture levels observed in KR plots in Chiquimula, Guatemala, four, seven, and 14 years after establishment (U = 13.1%) were on average 100% higher than in comparable conventional plots (U = 6.6%). This corresponds to additional 15 mm of water depth under the given conditions and provides a maize or bean crop with sufficient humidity to endure a dry spell of several days (CATIE, 2017).

In the Department of Lempira, Honduras, the practice of QS had been established before the El Niño period of 1997-1998 and hurricane Mitch in 1998. In both extreme climatic events QS proved its worth allowing farmers to harvest surpluses by mitigating impacts and increasing crop resilience. Thus, Lempira was able to send aid in the form of maize to other departments who suffered greater crop damage from the same weather phenomena (FAO, 2005).

How do QS & KR mitigate greenhouse gas emissions and capture carbon?

By abandoning the practice of clearing land of vegetation by fire, considerable amounts of GHG emissions can be avoided. There is limited literature about the specific mitigation potential of QS & KR. Ferreira (2008) estimated the avoided emissions for QS in Honduras at 22 779 kg of carbon dioxide equivalent (CO_2-eq) per hectare per year. The total global warming potential for QS, including abandoning burning, GHG fluxes between soil and atmosphere, and changes of carbon stocks in soil and vegetation, was estimated to be four times lower than for slash-and-burn (FIGURE 4).

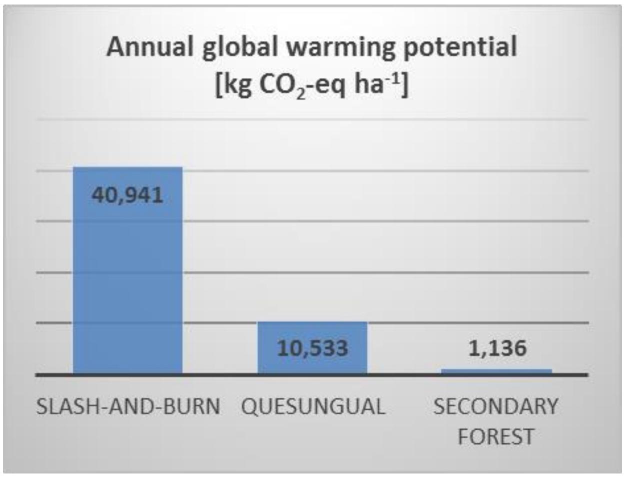

FIGURE 4: Annual GHG emissions of slash-and-burn, Quesungual agroforestry system, and secondary forest, expressed as carbon dioxide (CO_2) equivalent over a time horizon of 20 years. GHG considered are CO_2, methane and nitrous oxide. (After: Ferreira, 2008)

Another potential contribution of QS & KR to climate change mitigation is through carbon sequestration in soils. Figures presented by Ferreira (2008) indicate that soil organic carbon (SOC) increases with the age of a QS plot and that QS systems could potentially function as net carbon sinks if maintained for periods over ten years. However, more work needs to be done to understand this potential better. Further, as for all land use systems, it is not fully understood how to reliably determine the stability of SOC over periods of time long enough (100 to 1000 years) to consider the carbon sink stable (Lorenz & Lal, 2014).

Costs and funding for QS & KR

The capital cost for establishing a QS or KR plot is around USD 350 per hectare (Luis E. Álvarez Welchez, pers. comm.). The labour cost, usually family labour, is initially very high, but in the long term it is lower when compared to slash-and-burn agriculture (FAO, 2005, 2010, 2017). On severely degraded land where no trees from natural regeneration are present and planting material has to be purchased, the capital cost may increase. In QS, generally, a maize yield of around 3.2 tons per hectare can be attained with an application of NPK fertilizer at 70–20–50 kilograms per hectare. At the initial stage of QS & KR, relatively higher rates of mineral fertilizers may be required - associated with an additional cost - until the mineralization of tree cuttings sets free sufficient amounts of nutrients to obtain the expected yields (FAO, 2005).

When establishing QS or KR on land exhausted by slash-and-burn cultivation, during the first two years yields are usually lower resulting in lower food availability and lower incomes for the farmers. In a smallholder subsistence farming context, this can have serious implications for the food security of the farm households as they usually lack the financial resources to compensate these temporary yield reductions. This can constitute an important barrier to adoption for many farmers and may require an initial transition subsidy.

For the adoption of QS in Western Honduras, savings and loan clubs were an important financial mechanism to provide farmers with funds for the purchase of quality seeds and fertilizers and to compensate reduced yields and farm income experienced in the first two years of transition. By 'paying back' the transition subsidy to their own saving accounts, farmers were able to accumulate sufficient financial resources to invest in improved farming inputs, diversification of production or social projects and enabled the savings and loan clubs to give loans to other farmers planning to adopt QS. The transition from slash-and-burn cultivation to QS was further encouraged by linking any loan provided by the savings and loan clubs to the adoption of agricultural practices that eliminate the use of fire (Ayarza and Welchez, 2004).

Metrics for CSA performance of QS & KR

The performance of QS & KR related to **productivity and food security** can be determined by comparison of crop productivity, land productivity, cost-benefit ratios, net income from agricultural activities, and caloric intake from basic grains and other sources for farm households practicing QS or KR versus other practices under similar agro-ecological and socio-economic conditions.

To assess the performance related to **adaptation and resilience** to climate change, long-term observations of yields and yield variability are required that allow to compare performance under a wide range of climatic conditions that reflect both inter-annual variability and long-term trends in climate change. Long-term observations of household income from agricultural activities can be used to assess the effectiveness of diversification to increase resilience to climatic extremes and changes.

The assessment of performance related to the **mitigation** of climate change requires the measurement and quantification of carbon stocks and related change rates in soils and plant biomass and fluxes of major GHG (carbon dioxide, methane, nitrous oxide) in secondary forest, traditional agricultural systems and QS & KR agroforestry systems.

Interaction with other CSA practices

Despite the increased level of nutrient cycling and availability under QS & KR, the use of mineral fertilizers can significantly improve yields (CIAT 2009). In order to limit costs and GHG emissions related to fertilizer production and application, it is important to use fertilizers efficiently applying the principles of site-specific nutrient management (SSNM), i.e. right product (including organic and inorganic fertilizers), right rate, right time, and right place.

Case study: Adoption and benefits of Kuxur Rum in Guatemala

Based on Maradiaga (2015)

Smallholder agriculture in the Dry Corridor of Guatemala is characterized by subsistence farming on hillside locations based on maize and bean production. The naturally occurring dry forests are strongly affected by deforestation and degradation, driven by slash-and-burn cultivation and the uncontrolled collection of fuelwood. The loss of vegetation and unsustainable agricultural practices result in high susceptibility to erosion, declining soil

FIGURE 5: Long-term monthly average data of rainfall (R), effective rainfall (eR) and potential evapotranspiration (ETo) (in millimeters) in La Fragua, Zacapa, Guatemala. The graph illustrates the effect of the 'canícula' dry season - typically ocurring in the Dry Corridor of Central America during July and August - on the water supply for rainfed crop production: ETo exceeds R, which underlines the importance to maximize the water retention capacity of the soil. Effective rainfall is the fraction of rainfall expected to be stored in the soil after subtraction of deep percolation and surface runoff; calculated with the USDA Soil Conservation Service formula. Data source: ClimWat, FAO, 2006.

fertility and low water retention, increasing the vulnerability of farmers' livelihoods and their risk of food insecurity.

The situation is exacerbated by the impacts of climate change. Increasingly erratic and abnormal rainfall patterns, late onset of the rainy season, and the extended duration of the short dry season 'canícula' occurring in the middle of the rainy season (see FIGURE 5) often result in severe crop losses (60 to 100 percent). Many affected poor farm households adapt to the reduced availability of food by reducing the daily meals, often leading to chronic malnutrition.

In response to these challenges, in 2000, FAO in collaboration with the Ministry of Guatemala and with funding from the Spanish Agency for International Development Cooperation launched a programme with the objective to identify good agricultural practices to reduce the vulnerability and food insecurity of smallholder farmers. The programme focussed on the province of Chiquimula. Farmer field schools (FFS) were conducted to identify and promote suitable practices, bringing together the experience of local farmers and agricultural technicians, which resulted in the creation of Kuxur Rum (FIGURE 6).

The practice was initially promoted by 25 farmer trainers and adopted by 190 families in Chiquimula between 2001 and 2003. For further up-scaling in Chiquimula and four other provinces, a communication strategy was devised and executed to raise awareness of KR and its advantages for sustainable agricultural production, food security and climate change adaptation. With the support of the extension system and farmer promoters, by 2006, more than 7000 farms had adopted KR to validate it on at least 0.17 hectares, i.e. about half of their land, covering around 1100 ha overall.[4]

Adopter families reported an average increase of maize and bean yields of 50 and 9 percent, respectively. Higher yields, combined with

FIGURE 6: Farmer in a Kuxur Rum plot with common bean growing on mulches and residues of maize crop (Chiquimula, Guatemala)

training on post-harvest practices, also resulted in a better provisioning of households with grain, raising the number of months per year with grain reserves from 5.4 to 7.9 months for beans and from 2.6 to 6.7 months for maize after practicing KR for seven years.

Measurements showed higher contents of soil organic matter under KR, increasing with age of the system, and higher soil moisture contents throughout the canícula. Besides its contribution to increased crop productivity and yield stability under drought conditions, the improved soil quality allowed farmers to start vegetable production which improved the nutrition of farm households providing minerals, vitamins and protein.

The *G. sepium* trees in the agroforestry plots provide households with firewood (50 percent of household requirement per hectare – or more if coupled with the adoption of energy-saving stoves) which reduces the pressure on forests. They further provide wood for fences, construction, handicrafts, fodder for small cattle and chicken, and can be used for the production of foliar fertilizer and rodenticide.

[4] KR has been further promoted since then and the total area under KR system in Guatemala increased, although there is no official estimate. The Mancomunidad de Copanch'orti' (an association of four municipalities in Chiquimula province) alone reports 5000 ha as of 2017 (José Ramírez Maradiaga, pers. comm.).

Further reading

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