Chapter 10
Vetiver Production for Small Farmers in India

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Abstract Vetiver (*Vetiveria zizanioides*) is a perennial grass of Poaceae family, native to India. Vetiver production systems in Western Ghat region in India support livelihoods of small farmers. Vetiver systems have diverse economic and ecological uses. Vetiver is a major industrial crop and is grown for its essential oil that is used extensively world over in flavor and fragrance industries. Vetiver is also used in manufacture of handy-crafts, thatching houses, and organic compost production. Vetiver has been traditionally incorporated in the cropping systems of the region. Vetiver has a variety of environmental applications such as soil erosion control, phytoremediation, carbon sequestration etc. which are reviewed. Large scale cultivation of vetiver for essential oil production was initiated by using improved agronomic and field distillation methods covering an area of 250 ha in coastal Karnataka, a Western Ghats region, India, a region characterized by tropical climate with a well defined rainy season. The soils of the region are lateritic, of low pH below 5.0, and low to medium in fertility. Cultivation by adopting improved agronomy and field distillation was successful. The field root yield was estimated at 2.5 t ha^{-1}. The roots on steam distillation by conventional and improved methods produced 0.6–0.8 % and 1.0–1.2 % essential oil respectively. Fifty to seventy-five percent more net returns were obtained from improved agronomic and distillation methods in vetiver in comparison to traditional crops such as paddy, areca nut and cashew. This article shows that economic gains from vetiver oil production can help livelihoods of farmers while helping to maintain ecological sustainability in this region.

Keywords Vetiver oil • Flavor and fragrance industry • Large scale production • Improved agronomy and distillation • Economic returns • Environmental protection • Sustainable livelihoods

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10.1 Introduction

Sustainable agricultural systems are vital in Western Ghats regions of India which is one of most ecologically sensitive regions of the world. The local farmers who are resource poor have to adopt cropping systems which provide food, economic returns and at the same time provide ecological protection to the region. Vetiver (*Vetiveria zizanioides*), a native of India, known for its perfumery and medicinal value since ancient times (Lavania 2003b), has been a traditional crop of the region which provides economic returns to the farmers and ecological value. In Uttara Kannada and Dakshina Kannada districts in western Ghats region of south India (Fig. 10.1) vetiver is traditionally cultivated for its roots and essential oil in around 3,000 ha using conventional agronomic and distillation practices resulting in poor yields and low economic returns (Prakasa Rao et al. 2008). Vetiver is cultivated as a secondary crop, with major crops being paddy, areca nut and cashew. Vetiver has been a crop of choice for providing economic returns to farmers. The variety of uses of vetiver has been reviewed briefly and results of the study aimed to improve essential oil production and economic returns have been reported in following sections.

10.2 Economic and Environmental Uses of Vetiver

10.2.1 Essential Oil

Vetiver, a member of the family Poaceae commonly known as the *Khas-Khas*, *Khas* or *Khus* in India, is a perennial grass with thick fibrous adventitious roots which are aromatic and highly valued. They can grow up to 1.5 m high and form clumps as wide as 1 m. The oil extracted from its roots by hydro/steam distillation is one of the finest oriental perfumes with a persistent fragrance. The oil is used in the flavor and fragrance industries for the manufacture of soaps, cosmetics, perfumery, agarbatti (incense sticks), soft drinks etc. In blended perfumes, vetiver oil acts as an excellent fixative for volatile compounds. It is known for its cooling properties and hence used in aromatherapy.

The current worldwide production of vetiver oil is 250 t per year. This production volume is made up of a dozen different varieties of vetiver oil: Haiti (100 tonnes), Indonesia (80 tonnes), China (20 t), India (20 t), Brazil (15 t), Dominican Republic (12 t), Vietnam (3 t), El Salvador (2 t), Madagascar (2 t), Nepal (0.5 t), Reunion (Bourbon) (0.5 t) and Ghana (0.4 t) (Thwaites 2010).

Vetiver oil, with its heavy, woody and earthy character, is one of the perfumer's most basic and traditional materials. Chemical composition of vetiver oil is highly complex mixture of more than 150 sesquiterpenoid constituents of which vetiverols, their carbonyl compounds and esters, are the main constituents and their relative abundance normally establishes the oil quality. Three carbonyl compounds α–vetivone, β-vetivone and khusimol are considered the primary odour influencing compounds and are considered to be fingerprints of the oil in the perfumery

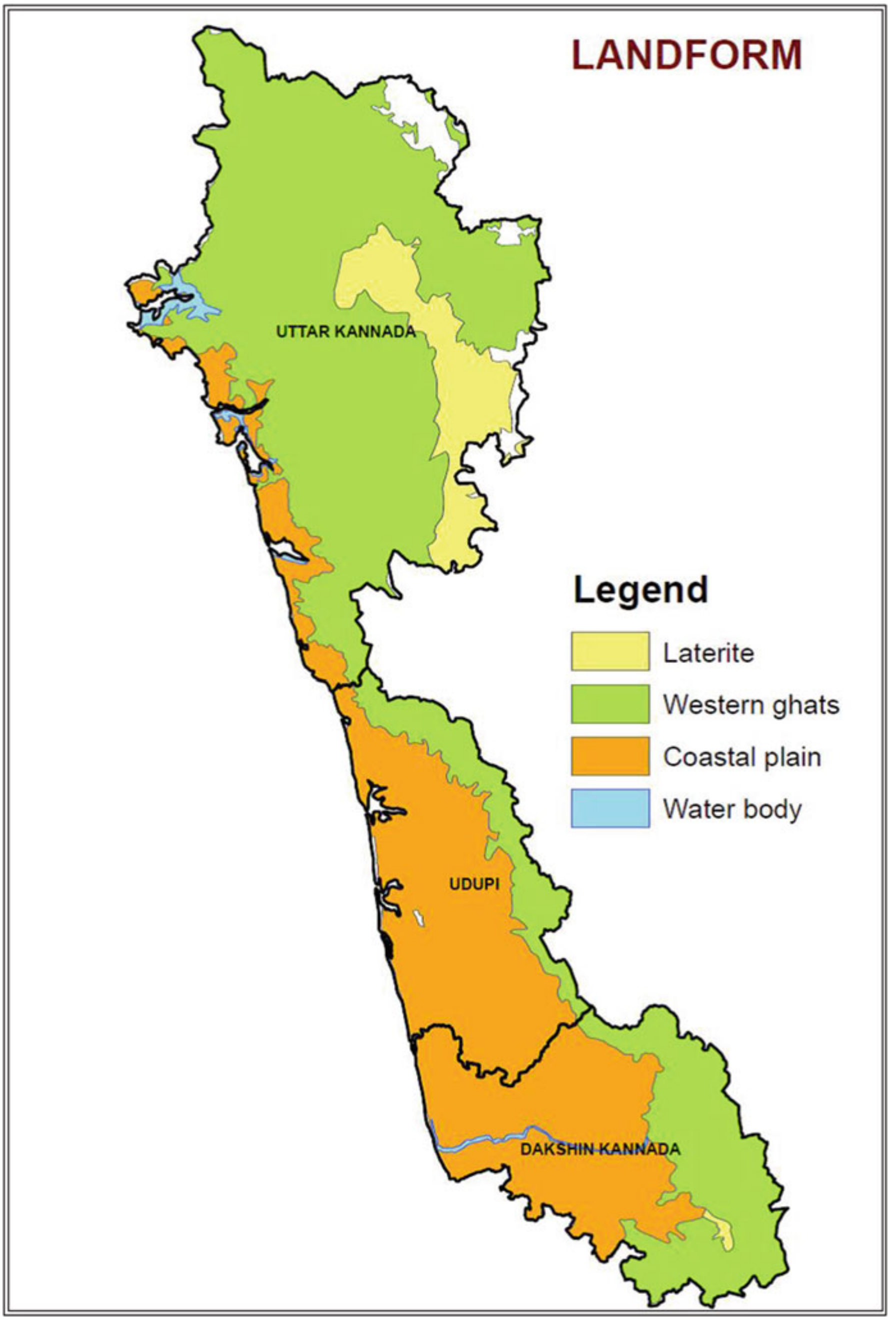

Fig. 10.1 Land forms in Uttara and Dakshina Kannada districts in Western Ghats area, India. The study area is ecologically sensitive region with complex landforms ranging from coastal to forest areas with lateritic soil formation

industries (Demole et al. 1995) even though they do not possess the typical odor characteristics associated with vetiver. Vetiver oil is used as part of the woody notes for luxury perfumes. The oils of vetiver, patchouli and sandalwood in combination with a jasmine and gardenia complex, is the base of the famous Crêpe de Chine note. In addition to its importance in classical perfumery, vetiver oil is also used as a base for many modern men's colognes (Guenther Ohloff 1994). The oil and its constituents are used extensively for blending oriental type of perfumes and floral compounds as well as in other cosmetic and aromatherapy applications. Vetiver oil is a main ingredient in 36 % of all western quality perfumes and 20 % of all men's fragrances (eg. Channel no. 5, Miss Dior, Cravache and Shalimar) (Thwaites 2010).

Vetiver oil is an extremely expensive ingredient with a precarious supply situation subject to the forces of nature and politics. This material is so crucial to industry, in fact, that in the wake of earthquake that struck Haiti in 2010, fragrance industry contributed to the earth quake relief operations (Thwaites 2010). The main reason for this increasing demand is its unique odor, for which it is used in both flavor and fragrance industries and inability to reconstitute this oil. The oil is preferred for 'base note' in flavors and fragrance production. Therefore, production systems have to be evolved for large scale cultivation and distillation of vetiver oil.

10.2.2 Medicinal Uses

Vetiver has been used for various ailments. Ayurvedic literature mentioned that plant is used as digestive, carminative stomachic, constipating, haematinic, expectorant, antispasmodic, antiasthmatic, antigout, anthelmintic, antimicrobial and diuretic. The roots are used for cooling the brain and also used in the treatment of ulcers. In addition to these, the plant is used for anemia, amenorrhea and dysmenorrheal (Jain 1991).

The tribals in India use the different parts of vetiver for many of their ailments such as a mouth ulcer, boils, epilepsy, burns, snake bite, scorpion stings, rheumatism, fever, headache, etc.; decoction of the roots has been used as tonic for weakness; the leaf juice as anthelmintic; the root vapor for malarial fever; the root ash is given to patients for acidity (Rao and Suseela 2000; Jain 1991; Singh and Maheshwari 1983).

Vetiver oil owes several beauty benefits and emotional effects. It balances the activity of the sebaceous oil glands, has deodorizing properties, and helps normalize oily skin and clear acne. It replenishes moisture in dry and dehydrated skin and has a rejuvenation effect on mature skin, as well as cuts/wounds/irritated and inflamed skin. When used regularly during pregnancy, vetiver oil reportedly prevents stretch marks (Lavania 2003a).

The vetiver oil possesses sedative property and hence it has been traditionally used in aromatherapy. The oil strengthens the central nervous system, and is helpful in overcoming depression, insomnia, anxiety, stress, tension and nervousness (Wilson 1995). It may be added to sports oil blends and massaged into muscles before and after sports. Vetiver oil is particularly useful for jet lag and for grounding and clarity while travelling (Shealy 1998). Researchers are exploring the therapeutic potential of this plant as it has more therapeutic properties which are not known (Bharath Bhushan et al. 2013).

10.2.3 Soil Erosion Control

Vetiver being a perennial grass and having deep and robust root system binds soil firmly. This characteristic has been used to control soil erosion, especially in sloppy lands and vulnerable conditions (Grimshaw 2008). Vetiver has been used world over for soil and water conservation in farm land, for land stabilisation: road, railway batter and river, for environmental protection: water and land pollution, and for combating climate changes (Truong 2011). In India on cropping land with 1.7 % slope, vetiver contour hedges reduced runoff (as percentage of rainfall) from 23.3 % (control) to 15.5 %, soil loss from 14.4 t/ha to 3.9 t/ha and sorghum yield increased from 2.52 t/ha to 2.88 t/ha over a 4 year period. The yield increase was attributed to mainly *in situ* soil and water conservation over the entire toposequence under the vetiver hedge system (Truong 1993). Relative to control plots, average reductions of 69 % in runoff and 76 % in soil loss were recorded from vetiver plots (Rao et al. 1992).

Results from Nigeria showed that soil physical and chemical conditions were ameliorated behind the vetiver strip for a distance of 20 m. Crop yields were increased by a range of 11–26 % for cowpea and by about 50 % for maize under vetiver management. Soil loss and runoff water at the end of 20 m runoff plots were 70 % and 130 % higher respectively in non-vetiver plots than vetiver plots. Vetiver strips increased soil moisture storage by a range of 1.9–50.1 % at various soil depths. Eroded soils on non-vetiver plots were consistently richer in nutrient contents than on vetiver plots. Nitrogen use efficiency was enhanced by about 40 %. This work demonstrates the usefulness of vetiver grass as a soil and water conservation measure in the Nigerian environment (Babalola et al. 2003).

In Brazil, vetiver could rehabilitate and maintain slopes affected by landslides even after 4 years of planting (Eboli et al. 2011) and also helped coastal erosion control (Luiz Lucena and Paula Leão 2011). Vetiver is used for large road stabilization projects in China, Malaysia, Thailand, Argentina, Venezuela (Smyle 2011).

In Thailand., vetiver is used in farmers' fields for soil and water conservation (Panklang 2011) and in Vietnam for sand dune protection, river bank erosion control, coastal erosion control, road batter stabilization (Van and Truong 2011) and in mountain slopes to prevent erosion (Quang et al. 2014). Vetiver is used in infrastructure stabilization in countries like Madagascar, S. Africa, Mozambique, Uganda, DR Congo, Guinea, Swaziland and for high absorption of heavy metals, phosphates and nitrates (Nöffke 2011). In India, vetiver cultivation in sloppy lands help to reduce run-off losses and control soil erosion (Fig. 10.2, Prakasa Rao et al. 2008).

10.2.4 Amelioration of Problem Soils and Phyto-Remediation

Vetiver tolerates extreme climatic variation such as prolonged drought, flood, submergence and extreme temperature from −14 to 55 °C, frost, salt and other adverse soil conditions such as soil acidity, salinity, sodicity and acid sulfate conditions (Van et al. 2008).

Fig. 10.2 Cultivation of vetiver on hill slopes in Western Ghats, India. Vetiver provides livelihood support besides protecting the soil from erosion

Vetiver is one such plant which is having extensive rooting system and can uptake heavy metals and been exemplified to rise in polluted soils (Yang et al. 2003; Chiu et al. 2006). The metal accumulating ability of this plant, coupled with metal tolerance and high shoot biomass, makes this plant ideal for extraction (Randloff et al. 1995; Truong and Baker 1998; Chen 2000). Vetiver could tolerate high Pb concentrations in soil (10,750 mg kg^{-1}) and had very good growth performance (Rotkittikhun et al. 2007). Uses of vetiver grass in relation to petroleum-contaminated soils are promising for amelioration of slightly polluted sites, to allow other species to get established and for erosion control (Brandt et al. 2006). Truong and Truong (2011) reported that vetiver has a very high capacity for uptake of N and P and can tolerate high levels of Cr, Cd, Cu, Pb and Zn. They have also reported phytoremediation of a contaminated land near an explosive factory in Australia where the soil is highly contaminated with nitrate and NH_3: soil total N up to 5 400 mg/kg, soil total NH_3 up to 1,220 mg/kg, water total N up to 18,300 mg/kg, water total NH_3 up to 12,300 mg/ kg.

A hydroponical experiment has shown that 1 mg/ml of cadmium increased chlorophyll content, root activity, and biomass to 2.2 % when compared to the control. The high level of Cd accumulation was seen in 30 mg/L with the cadmium accumulation of 93 and 2,232 mg/kg Cd in shoot and root respectively, but the cadmium treatment increased the catalase and the peroxidase activity in vetiver plant (Aibibu et al. 2010; Andra et al. 2009). Truong (1999) reported that the distribution of heavy metals in vetiver plant can be divided into three groups: very little (1–5 %) of arsenic, cadmium, chromium and mercury absorbed were translocated to the shoots, moderate proportion of (16–33 %) of copper, lead, nickel and selenium were translocated to the top and zinc (40 %) was almost evenly distributed between shoot and root. However, Yang et al. (2003), Roongtanakiat et al. (2007) and Singh et al. (2007) concluded that heavy metal accumulations were found higher in root than shoot.

Vetiver has been used for rehabilitation in oil contaminated sites as it helps in biodegradation of oil where the petroleum hydrocarbons are more. A greenhouse study has been conducted to study that the vetiver has the potential to degrade the crude oil sites in Venezuela. The results of this experiment indicated that vetiver grown in this contaminated soil have only slight effect but preferable in slightly contaminated soil (Brandt et al. 2006). Heavy metal contamination caused by lead (Pb) in the soil was studied in pot experiments, where vetiver can tolerate heavy metal like lead under EDTA application where EDTA is known to be the chelating agent, where increase in the Pb from the root to shoot was found (Chen et al. 2004).

Vetiver was used in treating coffee effluents in India (Nagesh Rao 2011). Vetiver can be considered a hyperaccumulator of Pb and Zn; heavy metal accumulation is high in roots than in shoot. Vetiver can tolerate salinity up to 12.0 dSm^{-1} pH up to 10.5 and soil ESP up to 55 (Patra 2011).

10.2.5 Carbon Sequestration

Vetiver due to its high biomass production and root growth has been proposed to be a potential candidate for terrestrial C sequestration (Lavania and Lavania 2009). Genotypes most suitable for C-sequestration have been developed (Lavania 2011). In India, estimates were made, based on field studies, the C sequestration potential of vetiver. They showed that vetiver sequesters 15.24 Mg C ha^{-1} $year^{-1}$ in shoot and roots, much higher than that for lemongrass with 5.38, palmarosa with 6.14, and trees with 2.92. In addition the benefit/cost ratio of vetiver, 2.3, is higher than that of rice, 1.97. It was estimated that vetiver cropping could sequester 150 Tg C per year in India, which is nearly 46 % of C emissions in India (Singh et al. 2014). As weather plays an important role in the biomass production and consequent sequestration of carbon, Prakasa Rao et al. (2011) have proposed modeling possibilities for vetiver based land use in west coast of Karnataka, India in relation to climate change. CO_2 emissions from and C sequestration by vetiver were studied in Thailand and vetiver was found to be good in the C sequestration (Taranet et al. 2011).

10.2.6 Other Uses of Vetiver

The other uses of vetiver are: harvested vetiver leaves is an input of agriculture-related activities viz. forage, mulching, composting. In the state of Karnataka, India, vetiver is planted along the field boundaries and cut every 2 weeks or less for use as fodder. Vetiver was found to have relatively higher structural carbohydrates as compared to native grass and rice straw. On the other hand, it also had optimal levels of crude protein, considered to be enough to maximize intake and digestion of the vetiver forage. It was concluded that vetiver may be used as ruminant feed if it is mixed with other good quality feed and forages (Anon 1990).

Vetiver leaves are used as a medium for mushroom cultivation since it contains cellulose, hemicellulose, lignin, and crude proteins. Many investigators have been successful in cultivating Oyster, shiitake, and straw mushrooms using vetiver as the medium for their growth (Chomchalow and Chapman 2003). Nootkatone compound in vetiver roots were able to disrupt termite behavior and physiology as a consequence of direct physical contact, ingestion, or exposure to the vapors. They also found that ingestion of wood treated with vetiver oil or nootkatone causes the progressive death of the protozoa living inside the termite gut, ultimately results in a progressive decline of its colony through starvation, as these termites rely on the protozoa for the digestion of their wooden food (Maistrello and Henderson 2001). In New Zealand, Greenfield (2002) observed that fungal attacks on the vetiver-mulched plants have virtually disappeared and there seem to be little, if any other pest action around the host plants. Thus vetiver mulch seems to have natural fungicide to stop the growth of the fungi which attack the crop plants.

The distilled roots are used for making handicrafts (Fig. 10.3) and the spent biomass is used for making paper and hardboards. In India, dried tops of vetiver have been used since ancient times for making makeshift huts (Fig. 10.4) and cabins as they provide cooling effects during the summer (Lavania 2003a).

Fig. 10.3 Vetiver provides alternate livelihood options to the small farmers of Western Ghats region, India. Handicrafts made from vetiver roots provide extra income to the farmers of the region

Fig. 10.4 Vetiver dry leaves are used to make temporary hutments for the farm workers in the Western Ghats area, India

The studies carried out at the Forest Research Institute, Dehra Dun, India revealed that pulps suitable for making strawboards can be made from vetiver by digestion with lime (Anon 1976). Kuhiran and Punnapayak (2000) described the process of producing ethanol from vetiver leaves by simultaneous saccharification and fermentation technique using *Trichoderma reesei.* Nimityongskul et al. (2003) reported that vetiver grass ash (VGA) can be a cement replacement material as a new building material specifically for the rural areas of the developing countries.

This paper presents the results of a study on large scale cultivation and distillation of vetiver adopting improved agronomic and distillation practices in the fields of nine farmers which was extended to an area of 250 ha.

10.3 Material and Methods

10.3.1 Site and Climatic Data

The study area is located in Uttara Kannada district of Western Ghat region in Karnataka state, India. Uttara Kannada district lies between 13.9220° N to 15.5252° N latitude and 74.0852 ° E to 75.0999° E longitude and covers an area of 10,291 km^2.

The area has a tropical climate with a well-defined south-west monsoon season between June and October, with an average annual rainfall of 4,016 mm. Maximum and minimum temperatures range from 25 °C to 32 °C and 19 °C to 26.3 °C respectively.

The soils of the area are moderately shallow, or moderately deep to very deep, somewhat excessively drained or well-drained, gravelly clay soils, associated with ironstone crust on the surface. The soils have low or medium base saturation, and low or medium cation exchange capacity. They are strongly to medium acidic, have medium to high organic carbon content. Constraints for agriculture are low base saturation, low nutrient status, crusting and steep slopes and moderate or severe erosion (Shiva Prasad et al. 1998).

Thirty farmers were selected in three villages (Uttara Koppa, Kachhodi, Kolegeri) of the region based on their land holdings and economic background. Majority of the farmers are illiterate (86.6 %) with an average land holding of 1–3 acres (76.6 %) and their economic status is very poor. Improved agronomic practices (3.2) and distillation methods (3.3) were tested in nine farmers' fields and were compared with the conventional practices of the region. The soil samples of the farmers' fields were analyzed (Table 10.1). The soils are acidic with low to medium fertility.

10.3.2 Agronomic Practices

The improved agronomic practices tested were as follows. Two varieties viz., local and Gulabi (developed by CIMAP) were evaluated and similar agronomic methods were followed for both the varieties. Vetiver nursery was raised in paddy fallow fields in March-April 2009. In June, 2009 shoots of the nursery plants were cut 25–30 cm above the ground and clumps were dug and split into slips (stem with

Table 10.1 Initial soil analysis of the sampling plots

Sampling plots	pH (1:2.5)	C (%)	Available N (kg/ha)	Available P (kg/ha)	Exchangeable K (kg/ha)
1	5.2	2.8	200.9	4.5	168.0
2	5.3	2.8	140.1	6.7	179.2
3	5.4	3.7	140.7	6.7	184.8
4	5.2	2.6	118.1	13.4	95.2
5	5.3	2.5	120.1	6.7	179.2
6	5.0	2.5	116.6	17.9	140.0
7	5.5	2.8	141.8	11.2	184.8
8	5.3	2.7	142.4	11.3	102.3
9	5.5	2.8	132.2	6.7	128.3
Mean	5.3	2.8	139.2	9.5	151.3

The analysis reveals that the soils are acidic with low to medium fertility
C organic carbon, *N* nitrogen, *P* phosphorus, *K* potassium

some portion of roots intact on them). Land was ploughed and the slips were planted in pits made at a spacing of 30 × 30 cm. A slip is placed vertically in each pit. Fertilizers were applied to supply N: 60 kg ha^{-1}, P_2O_5: 30 kg ha^{-1}, K_2O: 30 kg ha^{-1} and 5 t ha^{-1} farm yard manure was applied (Patra et al. 2004). Around 100,000 slips ha^{-1} were planted. Irrigation was not essential since it was grown as a rain fed crop. After 3 months of planting, weeding was performed.

Harvesting of roots was performed in April, 2010. The stem was cut at a height of 15–30 cm and the clumps were uprooted. Harvesting was done by manual digging with the help of spades wherein the entire clump is uprooted. The soil adhering to the roots was removed and roots were separated from shoots with the help of a knife. The roots were washed gently with running water in order to remove the adhering mud. The conventional agronomic practices included non-standardized plant population, plant spacing and fertilizer application.

Biometric data (mean root length/plant, shoot height/plant and no of tillers/plant) were recorded. The biomass yields of shoots and roots were recorded.

10.3.3 Distillation Method

In the conventional method of distillation, approx. 150 kg of vetiver roots were distilled for 72–80 h in a cylindrical still made of mild stainless steel of around 150–200 kg capacity. The unit is fixed to the ground with a provision of furnace to burn firewood to heat the water in the still directly (Fig. 10.5). The roots are placed on a mesh and water is filled below it. The still is connected to the condenser through a vapour line. The water is boiled and the steam vapour passes through the roots, vapourizing the oil which gets condensed in a coil type condenser by cooling water. The steam generation in this type of unit is as low as 15–20 kg/h. The condensate oil mixture is then separated through a series of oil separators (4–5 nos.) which are interconnected. The oil recovery is calculated as % of roots (w/w).

In the improved method of distillation, approx. 300 kg roots per batch are steam-hydro distilled for 18–20 h in cylindrical still made of high quality stainless steel cum steam generator of 500 kg capacity (Fig. 10.6) The cylindrical distillation still is placed on a square inbuilt boiler and calandria having smoke pipes which reduces the boiling time of water which results in higher steam generation rate of 120–150 kg/h and lesser fuel consumption (20–30 % of the conventional method). The still is placed on a specially designed furnace having fire grate, flue ducts and fire door for proper control of the firing and draft. The furnace is connected with a chimney of optimum height to maximize the air draft. A compatible stainless steel shell tube type condenser is used to get higher condensation capacity for cooling of the vapours which minimizes loss of oil. The condensed oil- water mixture is then passed through a specially designed stainless steel oil separator. The separator has an inbuilt baffle to maximize the retention time of the mixture thereby minimizing loss of oil along with the outgoing water from the separator. The oil recovery by the improved method was also recorded.

Fig. 10.5 Conventional distillation unit in a farmer's field in Western Ghats area, India. The traditional method of distillation of vetiver roots yield low essential oil yields, take more time and consume more fuel rendering the process less economical and environment friendly

10.3.4 Recycling of Biomass

In order to recycle the bio-wastes generated during cultivation and distillation of vetiver, vermicomposting of the wastes has been studied. Around 100 kg per batch of agro-wastes, which comprised of vetiver plant wastes and dry leaves from the forest trees are charged to the vermicompost pit with dimensions of 20 ft × 6 ft with 1.5 ft depth (1 ft below the ground level and ½ ft above the ground level). Cow dung available in the farm is mixed with water and this slurry is sprinkled in the pit. When the heat evolved during the decomposition of the material has subsided (15–20 days after heaping), 200 earthworms of species *Eudrilus eugeniae* were introduced in to each pit. Appropriate moisture (about 70 %) was maintained and the biomass was turned and mixed once in a week. Vermicompost produced is passed through a 2 mm mesh and stored in gunny bags. An average of 300 kg per pit per batch of vermicompost was produced by this method. Samples of the vermi-compost were analyzed for nutrients by standard method (Puttanna and Prakasa Rao 2002).

Fig. 10.6 Improved distillation unit and oil separator established in a farmer's field in Western Ghats area, India. The unit helps to recover more vetiver oil, consume less time and fuel making the process more economical and environment friendly

10.4 Result and Discussion

Soil characteristics – Initial soil analysis of the sampling plots are given in the (Table 10.1).

The initial soil analysis of the sampling plots reveals that soils are acidic with low to medium fertility.

10.4.1 Biometric Characteristics

The biometric parameters of the plants harvested in different sampling plots of conventional and improved agronomic methods are presented in the (Table 10.2). The mean root length was 43.18 cm and 47.58 cm, plant height was 113.42 cm and 118.3, no of tillers/plant was 41 and 46 respectively. The better growth with the improved agronomy is due to a better variety (cv. Gulabi) and better agronomic practices. Thus, introduction of improved agronomy offers increased productivity in this region.

Table 10.2 Biometric data of vetiver in the different sampling plots from three villages

Sampling plots	Mean root length/plant (cm)		Mean shoot height/plant (cm)		Mean no. of tillers/plant	
	Improved agronomy	Conventional agronomy	Improved agronomy	Conventional agronomy	Improved agronomy	Conventional agronomy
1	50.0	45.5	119.3	109.4	40	37
2	47.6	46.8	119.8	115.0	45	40
3	46.3	42.8	112.2	109.0	49	45
4	45.0	42.3	114.3	109.6	45	39
5	45.3	41.0	115.7	111.8	45	40
6	46.4	40.6	120.3	115.1	51	44
7	48.9	40.7	119.1	114.6	46	41
8	49.5	43.4	123.6	119.7	48	44
9	49.3	45.6	120.8	116.6	47	39
Mean	47.58 ± 0.52	43.18 ± 0.53	118.3 ± 0.82	113.42 ± 0.75	46 ± 0.70	41 ± 0.60

The root length, shoot height and number of tillers are found to be higher with improved agronomy

Table 10.3 Above ground and below ground biomass of the sampling plots of vetiver

Sampling plots	Mean root biomass/plant (g)		Mean shoot biomass/plant (g)		Mean root: shoot ratio (%)	
	Improved agronomy	Conventional agronomy	Improved agronomy	Conventional agronomy	Improved agronomy	Conventional agronomy
1	28.0	26.0	288.6	270.3	9.70: 90.3	9.61: 90.39
2	30.0	24.3	356.3	294.6	8.41: 91.59	8.24: 91.76
3	30.0	28.3	314.0	284.0	9.55: 90.45	9.96: 90.04
4	30.0	26.0	318.1	282.0	9.43: 90.57	9.21: 90.79
5	32.4	28.0	296.6	270.6	10.92: 89.08	10.34: 89.66
6	30.0	26.0	324.0	238.6	9.25: 90.75	10.89: 89.11
7	30.1	24.0	342.0	280.3	8.80: 91.20	8.56: 91.44
8	29.4	24.0	312.0	264.0	9.42: 90.58	9.09: 90.91
9	32.5	28.0	290.3	276.3	11.19: 88.81	10.13: 89.97
Mean	30.26 ± 0.42	26.06 ± 0.36	315.76 ± 4.27	273.41 ± 3.04	9.63 ± 0.42: 90.37 ± 4.27	9.55 ± 0.36: 90.45 ± 3.04

The root and shoot biomass are found to be higher with improved agronomy. However the root: shoot ratio in both the methods remains constant

10.4.2 Biomass Evaluation

Biomass evaluation was done in three randomly selected plants from nine plots. These plants were manually dug and biomass observations were taken on the separated shoots and roots. The biomass in shoots and roots was higher with improved agronomic methods than with the conventional methods (Table 10.3). This may be due to better biometrical values with improved agronomy as shown in Table 10.2.

Nearly 10 % of the plant's fresh biomass is located in the roots. The root: shoot ratio, rather, remained constant in both the varieties. The higher biomass with the improved agronomy can support higher vetiver oil production in the region.

10.4.3 Distillation of Essential Oil

Nine batches each of 100 kg roots have been distilled in conventional and field distillation units. The comparative essential oil recoveries from the conventional and improved methods of vetiver oil distillation are presented (Table 10.4).The oil yields in the two methods are 17 kg/ha and 25 kg/ha respectively.

The improved method of distillation gave 25–30 % higher oil recovery than the conventional method, besides reduced firewood consumption (150 kg as against 600 kg in conventional method) and man days (3 man days as against 18 man days in conventional method) and also distillation cost is reduced to 50 % in the improved method of distillation. The higher essential oil recoveries were also possible due to the improved design of the unit and oil separator. The essential oil recoveries are presented in the (Table 10.5). The improved oil separator reduced the oil losses and improved the recoveries by 22.6 %.

10.4.4 Vermicompost Production

On an average, 300 kg/pit/batch of vermicompost is produced. The analysis of vermicompost is presented (Table 10.6). The analysis reveals that it is rich in organic carbon and nutrients.

Table 10.4 Oil recovery in using conventional and improved distillation methods

Batch	% oil recovery	
	Conventional method	Improved method
1	0.8	1.2
2	0.7	1.3
3	0.6	1.2
4	0.9	1.1
5	0.7	1.3
6	0.8	1.1
7	0.9	1.2
8	1.0	1.3
9	0.7	1.1
Mean	0.78	1.2

About 50 % higher vetiver oil yield is obtained by the improved distillation method than the conventional method

Table 10.5 Essential oil yield from conventional oil separator and improved designed oil separator

Batches	% of oil in traditional oil separator	% of oil in improved designed oil separator	% increase in oil recovery
1	1.0	1.2	20
2	1.1	1.3	18
3	0.8	1.0	25
4	0.8	1.0	28
5	0.8	1.0	25
Mean	0.9	1.1	22.6

The improved method of distillation gave 25–30 % higher oil recovery than the conventional method

Table 10.6 Nutrient composition of vermicompost produced from vetiver waste

Vermicompost	Production of vermicompost kg/pit	pH	C (%)	N (%)	P (%)	K (%)
Pit -1	980	7.6	18.9	1.3	0.14	0.28
Pit -2	1,020	7.0	15.2	1.1	0.11	0.34
Pit -3	980	7.7	34.4	1.6	0.10	0.20
Pit -4	1,040	7.1	24.3	1.6	0.15	0.24
Pit -5	1,000	7.5	21.3	1.4	0.12	0.31
Mean	1,004	7.4	22.9	1.4	0.12	0.22

The average vermicompost production is around 300 kg/pit/batch and the analysis of the compost reveals that it is rich in organic carbon and nutrients
C organic carbon, *N* nitrogen, *P* phosphorus, *K* potassium

Table 10.7 Economics of the major and secondary crops of the region

Particulars	Paddy (Rs.)	Arecanut (Rs.)	Cashew (Rs.)	Vetiver-conventional method (Rs.)	Vetiver-improved method (Rs.)
Cost of cultivation/ha	33,125.00	70,750.00	36,500.00	1,05,750.00	89,500.00
Gross income/ha	45,000.00	1,20,000.00	90,000.00	1,70,000.00	2,12,500.00
Net income/ha	11,875.00	49,250.00	53,500.00	64,250.00	1,23,000.00

The net returns have increased by about 50–60 % with the intervention of improved vetiver agronomic and distillation technologies

10.4.5 Economics of Cultivation

The major crops of the region are paddy, areca nut, and cashew. Vetiver is cultivated as a secondary crop. The monetary returns/ha of major crops and vetiver were studied. The return from vetiver cultivation is more than the traditional crops (Table 10.7). Based on the results obtained in the selected farmers' fields, the improved agronomic and distillation technologies were adopted in 250 ha of the project area.

The improved methods reduced the cost of distillation by half, increased the oil recovery by 22 % thus increased the net returns by more than 50 %.

10.5 Conclusion

Large scale cultivation and distillation of vetiver was tested in a western Ghats region of Karnataka state, India using improved agronomic and distillation technologies. The improved agronomic methods along with recycling of agro-wastes have significantly increased the yield levels of vetiver root. Also, the improved method of distillation helped farmers to realize higher oil recoveries thereby producing higher oil yields. Based on the data obtained in farmers' fields, the improved methods tested in a large area of 250 ha of the region resulted in an increase of more than 40 % vetiver oil yields compared to the conventional methods; nearly 6 tones of vetiver oil was produced in the project area. Thus, we have shown for the first time that large scale cultivation and production of vetiver oil adopting improved agronomy and distillation is feasible that would improve the livelihoods of farmers while helping to maintain ecological sustainability in this region.

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