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Integrating land use plans in malaria control with mosquito repellent plants in homesteads in Tanzania

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Abstract

Apart from the conventional malaria control schemes over the decades, there is gradual growing interest in multipurpose plant species with repellence activity against mosquitoes and other nuisance organisms in the homesteads. Ethnobotanical study in selected districts in Tanzania employed statistical Use Value (UV) model to rank and recommend priority repellent plants used by local communities. The five top ranking repellent plant species according to UV analysis were *Ocimum basilicum, Hyptis suaveolense, Azadirachta indica, Cocos nucifera and* and *Schinus mole*. Qualitative assessment of repellence activity for selected plants was performed in different forms such as smoking, infusion and natural scent to validate repellence activity. Basic soil parameters viz. Ca, Mg, Na, P, N, organic matter, cation exchange capacity and pH from the plants habitats were determined to facilitate transplanting of recommended plants in new environments. Community perception on planting non-traditional crops on the home yards was assessed to aid in developing plans for integrating repellent plants among other land use priorities on the homesteads. The envisaged long term impact is creation of microclimate complex at rural homesteads simultaneously capable of providing diverse domestic needed plant products while controlling mosquitoes and other non-friendly organisms from the homesteads.

Keywords: Land use plan; Mosquitoes; Repellent plants; Malaria control; Tanzania

1 Introduction

The use of repellent plants against mosquitoes is a very old practice as one of alternative ways to fight malaria pandemic. There are a number of plants that are globally known for their repellent activity against mosquitoes. One of the most famous mosquito- repelling plants is Citronella grass, which is used by manufacturers to make citronella candles [1]. Other well-known mosquito repelling plants include Marigold, Catnip, Rosemary, Lavender, Lemon balm, Lemongrass, Cedar, Sagebrush, Bee balm/bergamot, Onion, Garlic, Tansy, Eucalyptus, Peppermint and Horsemint [2]. The research by lowa State University Department of Entomology presented the results of a study on common Catnip. Among their conclusions was the fact that an essential oil in Catnip is 10 times more effective at repelling mosquitoes than potent chemicals such as the chemical N-N-diethyl-meta-toluamide (DEET) [3]. DEET is currently one of the most common active ingredients in commercial mosquito and bug repellents [4]. Unfortunately, some studies indicate that DEET is also a dangerous chemical for humans, especially children [5,6]. Some of these repelling plants are not only effective against mosquito but also used to control ticks, flies, midges, chiggers, ants and snakes.

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In Tanzania, some plant species are broadly used within specific ethnic groups. Most of these plants are collected from the wild as twigs or wood and applied in diverse forms such as infusions, fumes or smoke to control nuisance insects [1]. Despite that these plants can emit scent against nuisance insects if planted close to the households, to date there is no appreciation of integrating such plants among other traditional land use priorities within the homesteads. Planting of these plants *ex-situ* and especially in home gardens is not a common practice among communities in Tanzania. As such, the main objective of this study is to advocate integration of mosquito repellent plants in land use plan as one of the approaches in the fight against malaria in the homesteads of the selected villages.

2 Material and methods

2.1 Description of the study area

Ethnobotanical information was generated from Mbezi, Msufini, Mvuleni and Mkiu villages in Mkuranga District in July to September 2019; Tende and Zombo villages in Kilosa District and Kitati village in Mpwapwa District in Tanzania. Selection of villages was objectively guided by the prevalence of malaria according to the statistics from the district malaria coordinating offices. The chosen villages were the ones with highest malaria scores. Selection of villages also considered representation of tribal diversities. It is known that each culture devised independent copying strategies against common social problems [7].

2.2 Data collection

Quota sampling method [8] was used to get the sample size for interview in this study for ensuring that every part of the village was represented. Semi structured questionnaires and focus group discussions were used in the collection of potential plants with mosquitoes repelling activity. The questionnaires were intended to get information on awareness of the plants used as mosquito repellents within the selected villages. Other sources of information were key informants, focus group discussions, participatory observation and market visits.

2.2.1. Ethnobotanical survey and identification of plant used for repelling mosquitoes

At least 5% of the households for each village were visited for questioning. From the ethno botanical survey, the statistical model of use-value (UV_s) by [9] was used to analyse results of plants used and to rank plants according to their preference by local communities.

2.2.2. Assessment of the repellence activity for the selected plants

In order to get the best way of using mosquito repellent plant in homesteads, technique used by [1] in Northern Tanzania was used. The first step involved gathering of the information from local people themselves on how each plant is used as a repellent. Key informants, participant observation and focus group discussions were used to supplement information gathered in house questionnaires. These local practices were demonstrated at the institute to confirm their activity in diverse forms such as smoke, scent/fumes, infusion or paste.

Use of Smoke

Demonstrations were performed to determine repellence activity for plants reported to be smoked. *Spyrostachys africana* (Mharaka) stem wood, *Cocos nucifera* husk and dry shoots of *Hyptis suaveolens* and *Ocimum basilicum* were smoked at the areas of mosquito's concentration.

Use of fumes or scent

Fresh shoots or twigs of *Clausena anisata* (Mvuje), *Sphaeranthus cythuloides* (Kiulaga nzuguni Gogo dialect) and *Schinus mole* (Mpilipili) were placed at the areas infested with mosquitoes. Experiments were set to observe the trends by which mosquitoes were avoiding these treatments.

2.2.3. Use of infusions

New bed nets were soaked in the infusions of most frequent plant species (*Hyptis suaveolens* and *Ocimum basilicum*). Untreated bet net was a negative control while positive control was a bed net treated with a conventional repellent (Ngao). Test was done in mosquito infested room. People were allowed to sleep in each bed while doing the observation. Herbal infusions were prepared by soaking 1 kg of each of ground shoots of fresh *Ocimum* and *Hyptis* plant materials in

5 litres of normal water at room temperature. Soaking was done for 5 minutes to allow nets absorb sufficient herbal materials. The number of mosquitoes alighting on the nets were counted systematically at the intervals of two hours from 2000 – 0400hrs. Counting was done immediately after putting lights on. To avoid variances during counting of alighting mosquitoes, counting was done at the same time by trained assistants. After each count, the lights were switched off for the next counting round. The species of mosquitoes could not be determined.

Application of herbal pastes on the skin

Another test involved applying paste of *Hyptis* and *Ocimum* on bare hand. The experiment was done by using starved and captivated mosquito at the Institute of Traditional Medicine. Bare volunteer hands both treated and untreated were exposed to hungry mosquitoes. This was a qualitative study to observe repellence potential of selected plant species.

Use of dark cloth

Three pieces of black cloth sheet (1mx 0.5m) were used to determine response of mosquitoes on the selected plant extracts. In this experiment, two black sheets of cloth were soaked in *Ocimum* and *Hyptis* infusions respectively. Third piece was a control. Triple treatments were left hanging by the wall in dark room painted whitish with door and windows open to allow free mosquito entry into the room. People were lying in the room to attract mosquitoes. Individual human subjects are differentially attractive to mosquitoes and other biting insects [10]. Around midnight at 23hrs, light was switched-on to drive insects to the hideouts (dark sheets).. Mosquitoes are more attracted to dark objects than to black and white patterns [11]. After mosquitoes had settled in their hideouts for 5 minutes, sheets were struck gently to observe swam of mosquitoes flying from each. This was a qualitative test as it could not allow counting of insects, rather to observe the sheet avoided or selected by mosquitoes on flee.

2.3 Testing of soil samples

For future domestication of selected plants, the information on type of soil and general description was recorded. Total of 89 soil samples were collected for determination of Ca, Mg, Na, P, N, organic matter, cation exchange capacity and pH. From each sampling pit, A and B horizons were picked and mixed–up prior lab analysis to avoid bias. Soil analysis was done at the Botany department, soil unit, University of Dar es Salaam. Test was done to establish baseline information required for agronomic projects on planting of mosquito repellents *ex-situ*.

2.4 Development of plans and design layout for adoption of the research findings

Iterative approach was used in this case. Before a final plan for planting mosquito repellent plants is prepared, a preliminary or interim report was made by gathering the results from all the related responses and observations. Consideration for design layout involved types of land use and plant species that are best suited for each land category. This was based on domestic division of labour, land suitability and status of present crop patterns and soil tillage systems. Social groups were approached to get real perception on planting of plants on their home yards. Existing farmers' group were sensitized to pioneer the initiative as one of pilot areas for testing. Local knowledge was used to document both negative and positive potential impacts of selected plants to the environment in case a plant has to be integrated in *ex-situ* planting. Negative potential impacts such as invasiveness, allelopathy, potential weed, rooting patterns for possible cracks on housing, hosting of scaring organisms such as snakes, undesired smell, allergic reaction etc. Positive impacts: element of agro-forestry and agro-ecosystems, shade and environmental amelioration from colourful foliage/flowers, cultural benefits just to mention few.

2.5 Voucher specimen

Voucher specimen were prepared and deposited at the Institute of Traditional Medicine herbarium for further reference with collection numbers. Though accession numbers are not completed in the institute's herbarium, all voucher specimen were assigned with collection numbers such as *Azadirachta indica* A. juss (OT98), *Capsicum frutescens* (OT99), *Clausena anisata* (willd) (OT 100), *Datura stramonium* L (OT102), *Entandrophragma busei* (OT103), *Hyphaene coriaria* (OT 104), *Hyptis suaveolense* (OT105), *Launaea cornuta* hoschst (OT106), *Pteleopsis myrtifolia* Engl (OT107), *Schinus molle* L (OT108), *Sphaeranthus cythuloides* (OT109), *Spyrostachys africana* Sond (OT110), *Vernonia amygadalina* Delile (OT111) and *Zanthoxylum chalybeum* Engl. (OT112).

2.6 Ethical consideration

Informant consent was obtained before generating ethno botanical information from local people. Village leaders were well informed on the subject and they assisted in convening meetings in the villages and for obtaining informal consent.

3 Results and discussion

3.1 Ethnobotanical information and plants used for repelling mosquitoes

A total of 295 respondents were interviewed through house to house questionnaires and group discussions. Nine key informants were interviewed. Market visit in Tende village in Kilosa district revealed that some plants such as *Zanthoxylem chalibeum* were sold in local markets for medicinal uses apart from mosquito repelling activity. Cross sectional walk revealed that *Azadirachta indica* and *Senna siamea* species were most common trees on the compounds. The age range of respondents was between 15-105yrs. Gander ratio is shown in table 1.

Table 1 Ethnobotanical information report in Mkuranga, Kilosa and Mpwapwa districts

District	Village	Group discussion (no of respondents)	Main tribe in the village	Age range	House hold questionnaire	
					Male	Female
Mkuranga	Mbezi	16	Zaramo	39-100	9	8
	Mkiu	80 Approx	Ngindo	18-90	9	17
	Mvuleni	14	Ndengereko	30-75	9	4
Kilosa	Tende	11	Gogo	25-105	8	7
	Zombo	21	Sagara	20-90	18	16
Mpwapwa	Kitati	25	Mixture	15-80	13	15
TOTAL		167			61	67

From the table above, house to house survey managed to sample almost the same number of female and males. The exception was for focus group discussions whereas women could not attend, and most of views and voices were for men. This may affect implementation of the actual planting on the home yards. Table 2 shows the list of mentioned plant species, their frequency of mention and use values. The maximum use value index is 1. Some plants though reported to have high activity against mosquitoes, but could not be found. Some were in regions far away such as Morogoro, Coast and Dodoma.

Table 2 Use values analysis results for plants reported as having repellence activity against mosquitoes in the study area

Vernacular name	Scientific name	Frequency of mention	Use value
Muarobaini (Swahili)	*Azadirachta indica* A. juss	20	0.15625
Mbaazi (Swahili)	*Cajanus cajan* (L) Druce	1	0.0078125
Pilipili kichaa (Swahili)	*Capsicum frutescens* L	1	0.0078125
Mvuje (Digo, Ndegereko)	*Clausena anisata* (willd) hook.f	11	0.0859375
Mnazi(Swahili)	*Cocos nucifera* L	19	0.1484375
Mchaichai (Swahili)	*Cympopogon citratus* (CD.)Stapf	1	0.0078125
Mtura (Swahili)	*Datura stramonium* L	1	0.0078125
Muongo (Swahili)	*Entandrophragma busei* Harms ex Engl	7	0.0546875
Mlala (Ndengereko)	*Hyphaene coriacea* Gaertn.	4	0.03125
Hangazimu (Swahili)	*Hyptis suaveolense* (L) poit	69	0.5390625
Mnukanuka (Swahili)	*Kedrostis foetidissima* cogn.	1	0.0078125

Mchunga (zaramo)	*Launaea cornuta* hoschst	1	0.0078125
Mlonge (Swahili)	*Moringa oleifera* Lam.	1	0.0078125
Tumbaku(Swahili)	*Nicotiana tabacum* L	1	0.0078125
Mavumbasi (Digo)	*Ocimum basilicum* L	125	0.9765625
Mgoji (Gogo)	*Pteleopsis myrtifolia* Engl.	4	0.03125
Mpilipili (Hehe)	*Schinus molle* L	13	0.1015625
Mjohoro(Swahili)	*Senna siamea* H.S. Irwin	2	0.015625
Kiulaganzuguni(Gogo)	*Sphaeranthus kirkii* Oliv. & Hiern	5	0.0390625
Mharaka (Swahili) mkulo(gogo)	*Spyrostachys africana* Sond	10	0.0078125
Mjifwi (Gogo)	*Vernonia amygdalina* Delile	1	0.0078125
Mnungu (Hehe, Zaramo)	*Zanthoxylum chalybeum* Engl.	1	0.0078125

3.2 Repellence activities of the priority and most frequent plants against mosquito

3.2.1. Herbal infusions

Bioactivity of herbal infusions against mosquitoes as applied on bed nets was verified. It is reported that the ideal repellent would repel multiple species of biting arthropods and remain effective for at least 8 hours [12]. In this study, the bed nets impregnated with the infusions of *O. basilicum* and *H. suaveolens* retained repellence activity for more than 8 hours at a dwindling efficacy. The counts of individual mosquitoes alighting on the herbal treated nets was less than 15 after 8 hours as compared to about 50 for negative control (plain bed net) and 0 count for a positive control (bed net treated with a standard mosquito repellent locally known as ngao). The efficacy of herbal infusion was lesser to the standard mosquito repellent (ngao). There are still openings for improving herbal infusions of the selected plants in case they have to be applied on bed nets for public use.

In a parallel test, mosquitoes completely avoided both black sheets treated with herbal infusions and the standard mosquito treated nets while the negative sheet was crowded up. This is the evidence that plant extracts are repellent against mosquitoes. This confirms practice of local people on the use of selected plant species on the same. *Ocimum* spp were field-tested in Guinea-Bissau, West Africa, where it is reported that fresh *O. canum* (also known as *O. americanum*) provided 63.6% protection from mosquito biting for 2 hours [13].

The recorded repellence activities for other plants in this study are supported in various studies. The leaf infusion of *Schinus molle* was reported as potential mosquito repellent in Mkiu village. Similarly Hexanic extract of the *S. molle* leaf showed good repellence (83.33%) at the highest concentration (0.075 mg/L) against the oriental cockroach [14]. The infusion of *Cympopogon citratus* or popularly known as Lemon grass is sprayed in the house to keep mosquito away. It is reported elsewhere [15] that Lemon grass oil could be used as an effective repellent against stable flies. Laboratory tests in Kenya showed that the essential oils of *C. citratus* are highly repellent to adult sand flies, *Phlebotomus duboscqi* at very low doses [16].

3.2.2. Application of herbal pastes on the skin

It was observed that insects avoided hands treated with pastes of *Ocimum* and *Hyptis* spp. The paste of test plants were applied on hand and then hand placed in the cage with captivated mosquitoes. The transparent catcher box of about 60 x 20 cm was filled with 2 days staved mosquitoes. This was purposely done to increase agility of mosquitoes toward blood. In a different case, there was a severe attack on negative control (hand not treated with a herbal paste). It was risky to expose bare hand without herbal paste in mosquito's cage, so hand was exposed and removed immediately after having noted response of mosquitoes. The observation is in consistent with a study in Brazil where *Hyptis* sp. is traditionally rubbed on the skin against mosquitoes [17].

3.2.3. Repellence by Smoke

Smoke is the most widely used means of repelling mosquitoes in the rural Tropics [18]. In the study area, shaves from the stem of *Entandrophragma busei* are burnt in the house to spells out the mosquitoes. The smoke of *Entandrophragma*

sp displayed considerable antifeedant activity against Spodotera insects [19]. The smoke from the burning husk of *Cocos nucifera* is commonly used to drive mosquitoes away. A mosquito species and smoke specific repellence was observed where *Anopheles* was repelled by coconut husks in New Papua Guinea (66% CI 17-86%) [20]. Smoke from the shoots of dry *Hyptis suaveolens* and *Ocimum basilicum* were effective for repelling mosquitoes. In West Africa the fresh aerial parts of the *H. suaveolens* are placed on charcoal and the resulting smoke repels the mosquitoes [13]. Fruits of *Capsicum fruitescens* are dried and burnt whereas a bitter smoke is driving mosquitoes away. This application is not popular and not effective as mosquitoes usually return as room is cleared of fumes. This coincides with report that the distillates of the fruits of *C. frutescens* have mosquito repellence and was only effective for 2.5 hours [21]. Smoke from a fresh leave of *Nicotiana tabacum* were reported in this study as capable of warding-off mosquitoes from the homesteads. In the experimental study Ethyle-acetate extract of *Nicotiana tabacum* showed repellent strength against adults *H. rufipesin* at 40%v/w concentration [22]. Fresh Moringa leaves of *Moring oleifera* are burnt to expel mosquitoes. In a different study [23], the phytochemicals derived from *M. oleifera* seeds extracts are effective mosquito vector control agents while [24] found that Methanol extracts of *M. Oleifera* leaves are good repellent agent for the control of *Aedes aegypti.* The part of *Cocos nucifera* or coconut mostly used in the study area for repelling mosquito is coconut husks. According to a new U.S. Department of Agriculture (USDA), compounds derived from coconut oil are better than DEET at repelling blood-sucking insects [25]. Leaves of *Senna siamea* are mixed with leaves of *O. basilicum*, then burnt. The pungent smoke drives mosquitoes away. A similar repellence study reveals that aqueous *Cassia siamea* leaf extracts have natural biopesticide properties [26]. Either dry or fresh leaves of *Vernonia amygdalina* are bunt to ward off mosquitoes. A study in West Africa showed that *V. amygdalina* extract was the most lethal to *Anopheles gambiae* pupae and caused 55% mortality of adult *A. gambiae* at concentration of 160 ml/L [27]. The mature wood of *Spyrostachys africana* is burnt, and the smoke drive out mosquito and snakes from the house. Stem wood can be cut into small particles and these be placed in the house. The smoke of *S. africana* is said to be toxic, and the exudates from the stem was reported by local people to be toxic in contact with eyes.

3.2.4. Scent or fumes from the fresh twigs

Some plant twigs emit strong scent or fume that drives mosquitoes away from the homesteads. In this study, *Hyptis suaveolense* and *Ocimum basilicum* are among popular repellents whereas fresh twigs are either placed at the entrances or indoors to expel mosquito. *Hyptis suaveolens* has an effective mosquito and various insects' repellent activity [28]. In Northern Tanzania, freshly picked and bruised twigs of *H. suaveolens* are hung in the house to bar entry of mosquitoes [29]. Essential oil extracted from the dried foliage of *O. Basilicum* has repellence activity against the adult female *Culex pipiens* [17] reported that. In another study [30], essential oils of *Ocimum basilicum* had repellence activities against female Anopheles.

Among the plants recorded for their repellence activity. Scent of fresh leaves of *Schinus molle* and *Clausena anisata* were effective against mosquitoes. Similarly, *Clausena anisata* leaf extracts have potential repellent activity against mosquitoes with an EC_{50} of 78.9 mg/ml (7.89 %) and 71.6 mg/ml (7.16 %) in the first 15 min after spraying [31]. In the study areas, *Azadirachta indica* Leaves and crushed seeds are used to chase mosquito away. In different studies [32,33] the fruit and bark extract of *A. indica* exhibited repellent activity at $p<0.05$ and the seed kernel extract at $p<0.01$ significance levels for two different mosquito *Culex* and female *Anopheles* respectively. The most prominent constituent of Neem is azadirachtin, which has been established as a pivotal insecticidal ingredient acting as an anti feedant, repellent, and repugnant agent and induces sterility in insects by preventing oviposition and interrupting sperm production in males [34]. It was reported in Mkiu village that whenever *Datura stramonium* is planted closed to the house it repels red ants and other insects including mosquitoes. Ethanolic leaf extract of *Datura stramonium* showed an effective larvicidal activity against *Anopheles stephensi* and *Culex quinquefasciatus* [35].

3.3 Determination of the suitable land parcels for planting environmentally friendly mosquito repellent plants

For comparative study of soil characteristics, total of 89 soil samples were collected for determination of Ca, Na, P, N organic matter, cation exchange capacity and pH. However, due to cost implications, only 12 samples were analyzed i.e six soil samples for *Ocimum basilicum* and six samples for *Hyptis suaveolens*. Two samples for each species were selected randomly from each district to make total of 6 samples for each species. Soil analysis was done at the Botany Department, soil unit, University of Dar es Salaam. The laboratory results are presented in table 3.

Most soils samples have pH slightly alkaline to neutral, moderate salt concentration and non-saline i.e low EC and sodium adsorption ration. Good textural class-sandy loam to loam indicating excellent water penetration/infiltration but high water retention capacity. Exchangeable base are moderately low for sample 1-3. Sample 1-4 have moderately low CEC indicating that the ability of the soil to retain and exchange the nutrients with plant root is excellent. Available

Phosphorus (P-PO4) levels are good and high for some locations, i.e. sample 2 and 8. A good pH is between (6-7.5) that the pH levels of nutrients are present in available forms.

Table 3 Results of laboratory physical and soil analysis

Sample code	Parameters soil texture			HO_2 field capacity	pH	EC	% total N	%organic matter	Available PO4 mg/100g	Exchangeable base				CEC Meg/100g
	%sand	%silt	%clay							Na	K	Ca	Mg	
1	43.5	33.0	23.5	80.5	7.70	188	0.374	7.09	0.26	0.93	6.2	9.26	4.26	56.7
2	55.5	19.2	25.6	83.14	7.64	91	0.231	5.711	0.38	1.10	5.8	7.50	4.11	52.7
3	33.4	44.7	21.9	81.22	7.44	91.7	0.195	5.514	0.25	0.93	5.4	7.20	5.21	48.17
4	60.00	25.00	15.00	70.15	7.01	105	0.12	3.41	0.28	0.83	5.8	10.70	6.28	35.22
5	32.5	43.5	24.00	70.84	8.42	132	0.10	2.56	0.24	1.52	6.1	9.10	6.07	37.19
6	21.00	50.00	21.00	72.15	7.07	115	0.16	3.71	0.38	0.73	5.3	10.10	6.48	36.20
7	25.5	48.5	24.00	74.84	6.30	122	0.13	2.50	0.31	1.41	5.3	12.01	6.23	36.31
8	50.70	26.00	15.00	71.15	7.01	105	0.12	3.11	0.22	0.63	5.7	10.20	6.28	35.22
9	35.5	43.5	24.00	80.84	8.32	131	0.16	2.52	0.24	1.52	5.1	8.10	5.03	34.11
10	24.00	52.00	21.00	74.15	5.07	125	0.19	3.41	0.38	0.73	4.3	11.10	6.48	36.20
11	25.5	41.5	24.00	64.54	6.40	122	0.11	2.50	0.31	1.41	5.3	11.01	5.21	38.13
12	27.5	43.1	24.00	77.81	5.40	132	0.15	2.30	0.11	1.111	5.5	10.01	6.33	35.11

Source: Charles Kweyunga-Lab technician at the University of Dar es salaam Tanzania

Results in table 3 were further analysed by using ordination technique to determine relationship between distribution of herbal species against selected soil parameters**.** The correlation between plants distribution and soil variable is presented in table 4.

Table 4 Weighted correlation matrix (Plants distribution vs. CEC,N,P and EC, pH)

Axes	1	2	3	4	Total inertia
Eigenvalues	.283	0.72	0.71	0.71	27.984
Species – environment correlations	.817	.000	.00	.00	
Test of significance of all canonical axes	F-ratio = 1.08				
	P-value = 0.26				

Test of significance for all canonical axes indicated P>0.05. This signifies that there is no correlation between plants distribution in relation to environmental variables within the surveyed districts. This is the advantage in the sense that selected plants are not restricted to a particular ecological region. They can be grown anywhere within the selected villages without prior modifications in the new sites.

3.4 Development of plans and design layout for integration of repellent plants among the village land use priorities

Successful integration of mosquito repellent plants among other rural competing land uses is reliant on some critical issues such as: (1)perception on malaria pandemic by communities (2) household land use arrangement and investment opportunities (3) preference on plant species (4) land suitability and status of present crop patterns. An equivalent view is reported [36] in Nepal that factors that influence farmers decision on tree growing are availability of land and labour, types of trees available, techniques, and risk involved in growing them, guaranteed benefits as well as markets for both forest products and employment of family labour. In the study area, malaria by itself is a social menace, and everybody would be relieved to see it being exterminated. Each home has experienced hostility of malaria. This makes perception on any malaria control programme much receptive and fast to adopt and adapt. Nevertheless, any new investment on the traditional family land depends on household decision arrangements. In the study area, men dictate on household new investments although the actual workforce on the farm is women and children. There must be a consideration of justice with respect to resource allocation for rural women within male-dominated households and as one of vulnerable

social classes that face the risk of alienation on land rights [37]. Involvement of women in planting and managing selected plant species on the family land is indispensable. Women are responsible for cleaning and planting on the home yards. It is auspicious that majority of respondents in the house questionnaires were women, and they acknowledged planting of repellent plants. This is an appreciable milestone to this initiative. Women are the traditional target for fetching water and make watering on drying seedlings. The problem of water scarcity was prominent all over the studied districts. Water sources were far away to the average of 1-2 km.

Integration of a new plant species among other traditional crops must consider prevailing socio-economic and the domain cultures of the target communities. Farmers in Ethiopia integrate trees with crops selectively and strategically based on the multiple-use values [38]. In the study area, selection of highly scoring species such as *O, basilicum* and *H. suaveolence* was in some villages dispirited by cultural perceptions and the morphology of some plants. Most local people are not used to tree planting even for common trees of economic value such timber species. Sensitization is required for implementation of any tree planting project. Planting of non-common wild varieties that are not key food crops or without immediate financial benefits is not in the culture of local people.

Available land area for the family is another consideration when planning for integration of mosquito repellent plants. There are differences between the determinant factors of agri-environmental measures (AEM) participation based on farms' utilized agricultural area, particularly between small and large farms [39]. The average family farm size in study area was 2 ha onwards. These are dedicated for food and traditional cash crops such as Cashew nuts and Coconut. Any additional crop to the farm area must not undermine these priority crops. Farm areas are relatively small thus constrain introduction of wide crowned tree species such as *Entandrophragma busei* irrespective of their potential in repelling nuisance organisms. Growth characteristics such as crown size and root system are important factor to consider when planning for a new plant to the homesteads. Trees with superficial running roots such as Neem tree must be planted at a distance from the homesteads, and consequently divest their worth in warding off mosquitoes from the households. Minor characters such as unpleasant smell and hosting of some scaring organism are vital when designing spatial addresses of repellent plants on the home yard. This study advocates planting mosquito repellent plants as opposed to suggestion in Rusinga in Western Kenya [40] that alternative strategy for fighting malaria vectors by clearing trees close to homesteads. Planting of repellent plants on the households compounds provides multiple uses to the livelihoods that will be missed if trees are cleared.

4 Conclusion

Despite the efforts by the government to emphasize on use of treated bed nets and other environmental measures, rural people to some extent are still using herbal materials against mosquitoes. The most common plants are *Ocimum basilicum, Hyptis suaveolense, Azadirachta indica, Cocos nucifera and* and *Schinus* Most of these plants are used indoors in various forms such as direct placement in the room or through smoking. They also serve other purposes besides repellence activity including shading, sources of firewood, food and medicine. Planting of wild varieties around the house is not a common practice though villagers accepted the intervention as a useful practice for barring mosquitoes in the vicinity. The intervention needs sensitization for it to become functional and sustainable. Gender factor is a mandatory and cannot be overemphasized. Women are the active managers of plants on the homesteads and the most touched by malaria ill effects in the family. This must come to focus in circumstances where cultures of the community suppress representation of women with regards to decisions on species selection and all other spatial arrangements on farm lands. Tree planting in the home yards may pose additional burden to women who must fetch water from a far distance to water seedlings. Factors such as size of the compounds and presence of other competing trees on the compound are crucial for planning purposes.

Generally acceptance of the planned programme may not be rapid, as planting of wild plant varieties is not in the custom of local people in the study area. Considerable effort is needed for changing mind-set.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors declare that they do not have conflict of interest in any of the information in this publication

Statement of informed consent

Informed consent was obtained from the local communities before generating ethno botanical information. The consent included permission to publish the information in any form to serve as one of the global efforts in malaria control.

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