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Original Article

Preliminary notes on distribution of Himalayan plant elements: A case study from Eastern Bhutan

Tshering Tobgye[1, 2] and Kitichate Sridith[1*]

[1] *Department of Biology, Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla, 90112 Thailand*

[2] *Yadi Higher Secondary School, Yadi, Mongar, 43003 Bhutan*

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Abstract

Vascular plant species composition surveys in the lower montane vegetation of "Korila" forest, Mongar, Eastern Bhutan, identified 124 species, which constitutes an important component of the vegetation. Findings revealed that majority of the species were herbs including pteridophytes (ferns and lycophytes) (48.3%), followed by trees (23.4%), shrubs (20.9%), small trees (4.8%), (4.8%), and climbers/creepers (2.4%). Plant species composition and the vegetation analysis showed that the vegetation falls in lower montane broad-leaf forest type containing *Castanopsis* spp. and *Quercus* spp. (Fagaceae). A vegetation comparison study of the area with lower montane forest in South-East Asia through literature revealed that the true Himalayan element distribution range ended in the North of Thailand where the Himalayan range ends. But surprisingly, the study found that some Himalayan elements could extend their southernmost distribution until North of the Peninsular Malaysia. Thus, it can be concluded that the Himalayan range had formed an important corridor.

Keywords: lower montane forest, Eastern Himalaya, Bhutan; far-east Asia, plant distribution

1. Introduction

Studies regarding vegetation structure, composition, and regeneration in the Himalayan region were carried out by several researchers (Bhattarai & Vetaas, 2003; Gairola *et al*., 2008; Hussain *et al*., 2008; Ohsawa, 1991b; Tripathi & Singh, 2009) but limited to Bhutan Himalayan ranges only. Even the comparative study of Himalayan plants in the Far East of Asia and Bhutan Himalaya by Ohsawa (1991) is limited to the vegetation of the Himalayan range. Further, most of the studies carried out so far focused on sustainable and better management of forest resources (Covey *et al.*,2015; Daranbant *et al*., 2007; Gilani *et al*.,2015; Moktan *et al*., 2008, 2009; Wangda & Ohsawa, 2006;). But the rich vegetation of the Bhutan Himalaya with intact vegetation in pristine form calls for genuine comparison of plant elements with that of Far-East Asia. In addition, Bhutan hosts one of the most extensive tropical humid montane rain forests on the Eurasian continent (Ohsawa, 1991) with well-preserved evergreen forests of warm temperate or subtropical zones and laurel leaved forests (Oshawa, 1991).

The forests along the mountain slopes of Korila in Eastern Bhutan show diverse patterns of species distribution owing to geographical variability. Mostly, plant species belong to broad-leaved lower montane forest type and the major component of the tree species of the area belongs to *Castanopsis* spp. and *Quercus* spp. (Fagaceae).The primary aim of the present study is to compare the plant species of Bhutan Himalaya at the Korilaforest with Far-East Asia to study distribution range and to describe the floristic composition of the lower montaneareas in the Eastern Bhutan Himalaya.

*Corresponding author
Email address: kitichate.s@psu.ac.th

2. Materials and Methods

The study area is located in eastern Bhutan at 91°14' to 91°25' N and 27°13' to 27°25' E at an elevation of 1,500 to 2,500 m asl., Figure 1, containing granite as parent material (Okazaki, 1987). The topography of the study site is characterized by gentle mountain slopes with varying degrees of habitat. The characteristics of soil found in the area are yellow brown mostly composed of silt loam, moist and non-sticky. The vegetation is mostly evergreen broad-leaved forest of the lower montane areas. All the vascular plants were collected twice a month from February to September 2014. The voucher specimens were deposited at National Herbarium of Bhutan, Serbithang, Thimphu (THIM). Percentages of the plant elements of different habitat types were analyzed and compared with the plant elements of different regions. The International Plant Name Index (IPNI) was followed to provide scientific and author's name.

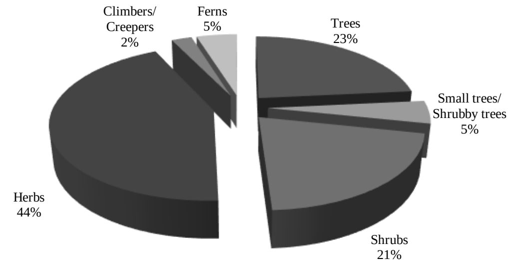

Figure 1. Plant elements of different habit types present in the lower montane vegetation of Korila,Mongar, Eastern Bhutan.

3. Results and Discussion

A total of 124 species of vascular plants had been identified as important component of the vegetation (Table 1). The analysis revealed that majority of the plant species were herbs including ferns and lycophytes (48.3%) followed by trees (23.4 %), shrubs (20.9%), small trees (4.8%) and climbers/creepers (2.4%) (Figure 1). The plant species composition shows that the vegetation of the area belongs to lower montane broad-leaf forest with majority of tree species comprising of *Castanopsis* and *Quercus* (Fagaceae) genera.

The comparison of plant elements of the study area with the countries of Far-East Asia through literature review of the flora (Figure 2) revealed that the plant elements could be categorized into four groups based on their distribution range (Figure 3): (1) The West Himalayan elements that have records in Afghanistan, Pakistan, Nepal, and India (Kashmir), (2) The East Himalayan elements that have records in East Nepal, Bhutan, South-East China, Myanmar, Northern Thailand, and Northern Vietnam, (3) The common elements of the Far-East Asia which have records in most countries in the Far-East of Asia including Eastern Nepal, Eastern India, Bangladesh, Sri Lanka, Myanmar, Thailand, whole range of Malaysia (Peninsula and Borneo), Indonesia (archipelagos), Vietnam, China, and Japan, and (4) The mainland of Far-East Asian elements which have records in Myanmar, Vietnam, Thailand, and Malay Peninsula (Table 1, Figure 3).

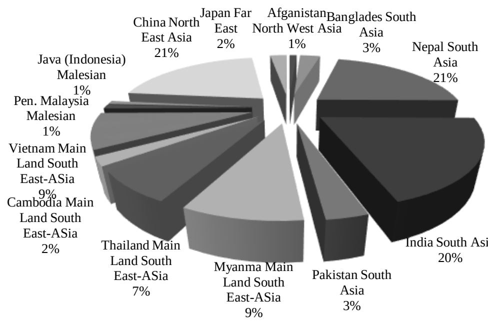

Figure 2. Percentage proportion of the plant elements of the study area in other regions.

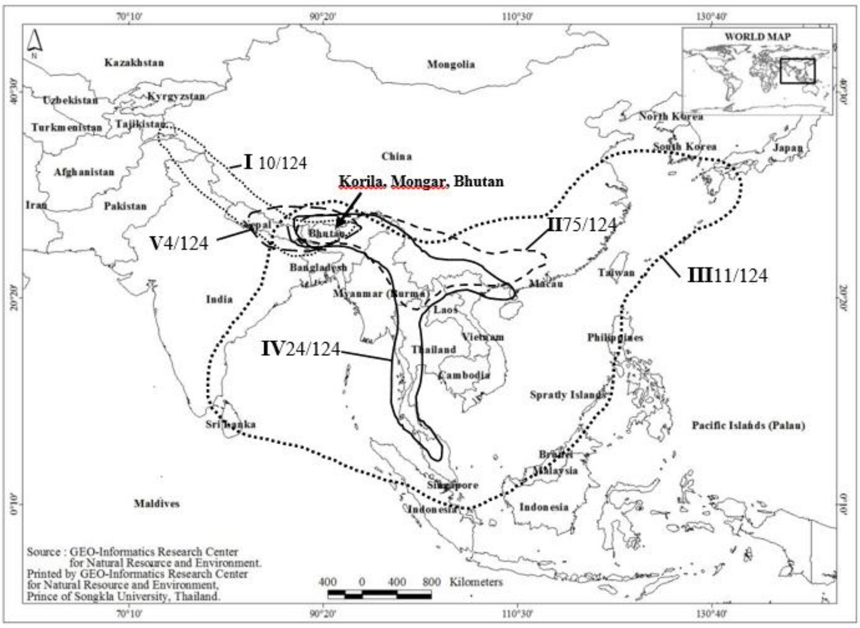

Figure 3. Distribution range of the plant elements of the lower montane vegetation of Korila, Mongar, Eastern Bhutan Himalaya – I: The West Himalayan elements; II: The East Himalayan elements; III: The common elements of the Far-East Asia; IV: The mainland Far-East Asian elements; V: The Central Himalaya endemics.

Table 1. List of plant elements found at the Lower Montane Forest of Korila, Mongar, Eastern Bhutan Himalaya, in comparison with their occurrences in different countries[1] in the Far-east Asia. The data was collected from available literature showing habits and the abundance class of each species.

Plant groups and Families	Species	Afg	PaK	Nep	Chi	Ind	Bng	JPn	Mym	Sri	Thai	Cam	Viet	MaL	Indo	Habit[2]	Abundance Class[3]
Lycophyte and ferns																	
Davalliaceae	*Nephrolepis cordifolia* (L.) C. Presl		×	×	×	×	×	×		×	×	×	×	×	×	F	2
Hypodematiaceae	*Leucostegia immersa* C. Presl			×	×	×			×		×	×	×	×		F	3
Lycopodiaceae	*Lycopodium clavatum* L.			×	×	×				×	×					F	3
Polypodiaceae	*Drynaria propinqua* (Wall. ex Mett.) J. Sm.			×	×	×			×		×		×			F	3
	Neocheiropteris normalis (D. Don) Tagawa			×	×	×			×		×		×			F	4
Woodsiaceae	*Athyrium thelypterioides* (Michx.) Desv.			×	×	×										F	5
Eudicots																	
Acanthaceae	*Justicia adhatoda* L.		×	×	×	×				×				×	×	H	3
	Mackaya indica (Nees) Ensermu			×	×	×				×						H	3
	Strobilanthes capitata (Nees) T. Anderson			×	×	×			×							H	3
Aceraceae	*Acer campbellii* Hook. f. & Thomson			×	×	×			×				×			T	3
Actinidiaceae	*Saurauia roxburghii* Wall.			×		×			×		×					ST	4
Adoxaceae	*Viburnum cylindricum* Buch.-Ham. ex D. Don			×		×										ST	4
	V. erubescens Wall.		×	×	×	×			×		×		×		×	ST	4
Anacardiaceae	*Rhus chinensis* Mill.			×	×			×	×		×	×	×			S	3
Apiaceae	*Centella asiatica* (L.) Urb.		×	×	×	×		×	×		×		×			H	5
	Hydrocotyle himalaica P. K. Mukh.			×	×	×	×									H	4
Araliaceae	*Hedera nepalensis* K. Koch			×	×								×			ST	4
Aristolochiaceae	*Aristolochia griffithii* Hook. f. & Thomson ex Duch.			×	×	×	×									H	2
Asteraceae	*Ainsliaea latifolia* (D. Don) Sch. Bip.			×	×	×	×		×		×		×		×	H	3
	Dichrocephala integrifolia (L. f.) Kuntze				×		×					×	×			H	3
	Galinsoga parviflora Cav.			×	×	×										H	2
	Parthenium hysterophorus L.			×	×	×										H	3
	Pseudognaphalium affine (D. Don) Anderb.			×	×	×		×	×				×		×	H	3
	Sonchus oleraceus L.			×	×	×										H	3
Balsaminaceae	*Impatiens spirifer* Hook. f. & Thomson			×	×	×										H	2
	I. stenantha Hook. f.			×	×	×										H	2
Berberidaceae	*Berberis griffithiana* C.K. Schneid.			×	×	×										S	3
Boraginaceae	*Cynoglossum furcatum* Wall.		×	×	×	×		×			×		×			H	2
Brasicaceae	*Nasturtium officinale* W.T. Aiton			×	×	×							×	×		H	2
Campunulaceae	*Lobelia pyramidalis* Wall.			×	×	×			×		×		×			H	4
Cannabaceae	*Cannabis sativa* L.			×	×	×										H	3
Caprifoliaceae	*Leycesteria formosa* Wall.		×	×	×	×			×							H	2
Caryophyllaceae	*Stellaria media* (L.) Vill.	×	×	×	×											H	3
Daphniphyllaceae	*Daphniphyllum chartaceum* K. Rosenthal		×	×	×	×							×			ST	4

Table 1. Continued

Plant groups and Families	**Species**	**Afg**	**PaK**	**Nep**	**Chi**	**Ind**	**Bng**	**JPn**	**Mym**	**Sri**	**Thai**	**Cam**	**Viet**	**MaL**	**Indo**	**Habit**[2]	**Abundance Class**[3]
Elaeocarpaceae	*Elaeocarpus lanceifolius* Roxb.			×		×			×		×	×	×			ST	3
Ericaceae	*Agapetes incurvata* (Griff.) Sleumer			×	×	×	×									S	3
	Gaultheria fragrantissima Wall.			×	×	×	×			×			×			S	4
	G. griffithiana Wight			×	×	×			×				×			S	4
	Lyonia ovalifolia (Wall.) Drude		×	×	×	×	×				×	×	×			S	3
	Rhododendron arboreum Sm.			×	×	×				×	×		×			ST	4
	R. falconeri Hook. f.			×	×	×										ST	3
	R. maddenii Hook. f.			×	×	×			×		×		×			ST	3
	Vaccinium retusum (Griff.)			×	×	×	×									S	3
	Hook. f. ex C.B. Clarke																
	V. vacciniaceum (Roxb.) Sleumer			×	×	×	×									S	3
Euphorbiaceae	*Macaranga denticulata*			×	×	×			×		×		×			ST	3
	(Blume) Müll. Arg.																
Fabaceae	*Albizia sherriffii* E. G. Baker			×	×	×			×							T	3
	Desmodium confertum DC.			×	×	×										S	3
	Indigofera heterantha	×	×	×	×	×				×						S	3
	Wall. ex Brandis																
	I. tinctoria L.			×	×	×								×		S	3
	Parochetus communis			×	×	×			×	×	×		×	×		H	4
	Buch.-Ham. ex D. Don																
	Trifolium repens L.			×	×	×										H	4
Fagaceae	*Castanopsis hystrix*			×	×	×			×			×	×			T	4
	Hook. f. & Thomson ex A. DC.																
	C. indica (Roxb. ex Lindl.) A. DC.			×	×	×	×		×		×		×			T	5
	C. tribuloides (Sm.) A. DC.			×	×	×			×		×					T	5
	Quercus lamellosa Sm.			×	×	×										T	4
	Q. c.f. *lanata* Sm.			×	×	×										T	4
	Q. oxyodon Miq.			×	×	×			×							T	4
Gentianaceae	*Swertia bimaculata* (Siebold & Zucc.)			×	×	×		×	×				×			H	4
	Hook. f. & Thomson ex C.B. Clarke																
Geraniaceae	*Geranium nepalense* Sweet	×	×	×	×				×		×		×			H	3
Gesneriaceae	*Aeschynanthus parasiticus*			×	×	×										E	2
	(Roxb.) Wall.															H	
Hamamelidaceae	*Exbucklandia populnea*			×	×	×			×		×		×			S	2
	(R. Br. ex Griff.) R.W. Brown																
Hydrangeaceae	*Dichroa febrifuga* Lour.			×	×	×			×		×	×	×			S	3
	Hydrangea heteromalla D. Don			×	×	×			×							S	3
	Philadelphus tomentosus			×	×	×										S	3
	Wall. ex G. Don																
Hypericaceae	*Hypericum choisyanum*		×	×	×	×			×							H	4
	Wall. ex N. Robson																
Lamiaceae	*Callicarpa arborea* Roxb.			×	×	×	×		×		×	×				T	3
	Leucas aspera (Willd.) Link			×	×	×					×					H	3
	Prunella vulgaris L.			×	×	×		×	×							H	3
Lauraceae	*Persea chartacea* Kosterm.			×	×	×										T	4
	P. fructifera Kosterm.			×	×											T	4
Magnoliaceae	*Magnolia champaca* (L.)			×	×	×										T	3
	Baill. ex Pierre																
Mazaceae	*Mazus surculosus* D. Don			×	×	×										H	3
Melastomataceae	*Melastoma normale* D. Don			×	×	×										S	3

Table 1. Continued

Plant groups and Families	Species	Afg	PaK	Nep	Chi	Ind	Bng	JPn	Mym	Sri	Thai	Cam	Viet	MaL	Indo	Habit[2]	Abundance Class[3]
Meliaceae	*Toona ciliata* M. Roem.		×	×	×	×	×			×	×	×	×			T	3
Myrsinaceae	*Ardisia macrocarpa* Wall.			×	×	×										ST/S	4
Oxalidaceae	*Oxalis corniculata* L.		×	×	×	×										H	4
	O. griffithii Edgew. & Hook. f.		×	×	×	×										H	3
Phytolaccaceae	*Phytolacca acinosa* Roxb.			×	×	×		×	×				×			H	2
Plantaginaceae	*Plantago erosa* Wall.			×	×								×			H	4
Polygalaceae	*Polygala arillata* Buch.-Ham. ex D. Don			×	×	×			×	×	×	×	×			H	4
Polygonaceae	*Aconogonum molle* (D. Don) H. Hara			×	×	×										H	4
	Fagopyrum dibotrys (D. Don) H. Hara			×	×	×			×							H	4
	Persicaria capitata (Buch.-Ham. ex D. Don) H. Gross			×	×	×										H	4
	P. nepalensis (Meisn.) H. Gross			×												H	4
	Rumex nepalensis Spreng.	×	×	×	×	×		×	×				×			H	4
Primulaceae	*Lysimachia japonica* Thunb.			×	×			×								S	4
Rosaceae	*Duchesnea indica* (Andrews) Teschem.	×	×	×	×	×			×							S	5
	Fragaria nubicola (Hook. f.) Lindl. ex Lacaita	×	×	×	×	×			×							H	5
	Neillia rubiflora D. Don			×	×	×										S	3
	Potentilla sundaica (Blume) W. Theob			×	×	×										H	5
	Prunus nepalensis (Ser.) Steud.			×	×	×										T	3
	Rubus ellipticus Sm.		×	×	×	×			×	×	×		×			C	5
	R. rosifolius Sm.			×	×	×		×	×		×		×			C	5
	Spiraea micrantha Hook. f.			×	×	×										S	3
Rubiaceae	*Mussaenda roxburghii* Hook. f.			×		×					×					C	3
	Rubia manjith Roxb. ex Fleming			×	×	×										H	5
	Wendlandia grandis (Hook. f.) Cowan			×	×	×	×		×							T	3
Rutaceae	*Murraya koenigii* (L.) Spreng.		×	×	×	×				×	×		×			ST	4
Saururaceae	*Houttuynia cordata* Thunb.			×	×	×		×			×		×			T	5
Solanaceae	*Solanum viarum* Dunal			×	×	×		×			×		×			ST	4
Symplocaceae	*Symplocos dryophila* C.B. Clarke			×	×	×			×		×		×			ST	5
	S. glomerata King ex C.B. Clarke				×	×										ST	5
	S. sumuntia Buch.-Ham. ex D. Don			×	×	×		×	×		×		×			ST	5
Theaceae	*Schima wallichii* (DC.) Korth.			×	×	×			×		×		×			T	5
	Eurya acuminata Wall.			×	×	×			×	×	×		×			ST	4
Thymelaeaceae	*Daphne bholua* Buch.-Ham. ex D. Don			×	×	×	×		×				×			T	5
Urticaceae	*Boehmeria nivea* (L.) Gaudich.			×	×						×	×	×			H	3
	Elatostema lineolatum Wight			×	×	×			×	×	×					H	3
	E. sessile J.R. Forst. & G. Forst.			×	×	×										H	3
	Girardinia diversifolia (Link) Friis			×	×	×				×						H	3
	Pilea scripta (Buch.-Ham. ex D. Don) Wedd.			×	×	×			×							H	3
Violaceae	*Viola yunnanfuensis* W. Becker			×	×	×										H	4
Monocots																	
Araceae	*Arisaema griffithii* Schott			×	×	×										H	2
	A. nepenthoides (Wall.) Mart. ex Schott & Endl.			×	×	×			×							H	2

Table 1. Continued

Plant groups and Families	Species	Afg	PaK	Nep	Chi	Ind	Bng	JPn	Mym	Sri	Thai	Cam	Viet	MaL	Indo	Habit[2]	Abundance Class[3]
Poaceae	*Oplismenus hirtellus* (L.) P. Beauv.			×	×	×	×									H	3
Asparagaceae	*Polygonatum punctatum* Royle ex Kunth			×	×	×	×				×		×			H	3
Orchidaceae	*Arundina graminifolia* (D. Don) Hochr.		×	×	×	×			×	×	×		×			Ot	2
	Calanthe mannii Hook. f.			×	×	×			×				×			Ot	+
	C. plantaginea Lindl.			×	×	×										Ot	1
	Coelogyne corymbosa Lindl.			×	×	×										Oe	1
	Dendrobium candidum Wall. ex Lindl.			×	×				×							Oe	+
Zingiberaceae	*Cautleyagracilis* (Sm.) Dandy			×	×	×					×		×			H	+

[1] **Countries: Afg**– Afghanistan, **Bng** – Bangladesh; **Mym** – Myanmar; **Cam** – Cambodia, **Chi** – China; **Ind** – India; **Indo** – Indonesia; **JPn**– Japan; **Mal** – Malaysia; **Nep** – Nepal; **PaK** – Pakistan; **Sri** – Sri Lanka; **Thai** – Thailand; **Viet** – Vietnam.[2]**Habits**: C – Climber/Creeper; EH – Epiphytic herb; F – Fern/ Lycophyte; H – Herb; S – Shrub; Ot – Terrestrial orchid; Oe – Epiphytic orchid; SM – Small tree/ Shrubby tree; T – Tree.[3]**Cover-abundance scale**: + = occurring as a single or few (≤ 5) individual(s) with no measurable cover; 1= occurring as several individuals but with cover less than 20 % in a selected plot; 2= cover up to 20% in a selected plot; 3 = cover up to 50% in a selected plot; 4 = cover up to 75% in a selected plot; 5= common everywhere in the area studied.

3.1 Plant species richness and abundance

The species diversity analysis of herbaceous plants showed that many shade dwelling herbs and pteridophytes were among the most diverse groups. The herb includes *Centella asiatica*, *Hydrocotyle himalaica* (Apiaceae), *Justicia adhatoda*, *Mackaya indica*, *Strobilanthes capitata* (Acanthaceae), *Lobelia pyramidalis* (Campanulaceae), *Oxalis corniculata*, *O. griffithii* (Oxalidaceae), *Swertia bimaculata* (Gentianiaceae), *Aconogonum molle*, *Fagopyrum dibotrys*, *Persicaria capitata* (Polygonaceae), *Boehmeria nivea*, *Elatostema lineolatum*, *Girardinia diversifolia* (Urticaceae), *Viola yunnanfuensis* (Violaceae) and pteridophytes consists of *Leucostegia immersa* (Hypodematiaceae), *Neocheiropteris normalis* (Polypodiaceae), *Athyrium thelypterioides* (Woodsiaceae), *Lycopodium clavatum* (Lycopodiaceae). The presence of these species indicates a rich ground cover of the dense forest. And mostly, some of these species (*Swertia bimaculata)* could be seen only in primary forest (Oshawa, 1987). This implies that there are lesser disturbances in this study area. Nonetheless, the presence of *Nephrolepis cordifolia* (Davaliaceae), *Melastoma normale* (Melastomaceae) species indicates some disturbances; but low abundance-class affirms that the disturbance was too minimal. It is also the feature of disturbances at the edge of the vegetation or the characteristic change shown by the heath forest with low nutrient area (Oshawa, 1987; Whitmor, 1975, 1984).

The family Fagaceae appeared to be the major component of the vegetation with its maximum record in the study area: *Castanopsis hystrix*, *C. indica*, *C. tribuloides*, *Quercus lamellose*, *Q.* c.f. *lanata* and *Q. oxyodon*. The abundance-cover classes of all the elements in the study area revealed the characteristics of primary vegetation containing broad-leaf oak forest, the vegetation type explained by Ohsawa (1987), with fewer or no disturbance(s). However, many secondary or pioneer species such as *Schima wallichii*, *Eurya acuminate* (Theaceae) and *Daphne bholua* (Thymelaeaceae) could be found with high abundance-cover classes (3-5) in some selected places (Table1). It, nonetheless, provides conclusive evidence that there might have been some disturbance in the past but it could initiate the natural recovery of the plant community.

Interestingly, the occurrence of prominent tree elements like *Daphniphyllum chartaceum* (Daphnephyllaceae), *Elaeocarpus lanceifolius* (Elaeocarpaceae), *Agapetes incurveta*, *Gaultheria fragrantissima*, *G. griffithiana*, *Lyoniaovalifolia*, *Rhododendron arboreum* (Eriaceae), *Symplocos dryophila*, *S. glomerata*, *S. sumuntia* (Simplocaceae) and others in a very high proportion along with significant record of herb species reveals that the vegetation type belongs to a highland heath forest (Oshawa, 1987; Whitmore, 1975, 1984) that occurs along with the broad-leaf lower montane vegetation.

3.2 Probable distribution ranges and patterns

Findings reveal that Eastern Bhutan Himalaya had shared at least one-fifth of recorded plant elements with adjacent regions in terms of distribution range and patterns as depicted by regional plant distribution comparison for selected countries (Figure 2). The figure shows that Nepal and South-West China with 21% and North and East India with 20% as the main region hosting maximum range of plant species in common with Eastern Bhutan Himalaya. It is also interesting to find same plant elements in Myanmar (9%), Thailand (7%), and Vietnam (9%) in the Far-east Asia. Some elements, though in less percentage, could also be seen in Afghanistan (1%), Bangladesh (3%) and Pakistan (3%); and in the Far-east Asian countries like Cambodia (2%), Japan (2%), Java-Indonesia (1%), and Peninsular Malaysia (1%). So, based on the distribution range recorded in the taxonomic literature supported by the flora of concerned region, the plant elements could be broadly grouped into five (Figure 3):

I. *West Himalayan elements*: It spreads along the West range of the Himalaya from western Bhutan through the North of India, Nepal, Pakistan, and Afghanistan (Figure 3I). These elements could be considered as the '*true*' Himalayan elements as they occur only in this Himalayan range e.g. *Hydrocotyle himalaica* (Apiaceae), *Galinsoga parviflora, Sonchus oleraceus* (Asteraceae), *Vacciniumretusum*, *V. vacciniaceum*, (Ericaceae), *Neillia rubiflora, Potentilla sundaica*, *Prunus nepalensis* (Rosaceae), *Wendlandia grandis* (Rubiaceae), etc.

II. *East Himalayan elements*: It continues along the East range of the Himalaya from eastern Bhutan through the North of India, Myanmar, South China, northern Thailand, northern Laos, northern Vietnam and selected species might have their distribution range to Japan (Figure 3II). These elements could also be considered as the '*true*' Himalayan elements as they occur only in East Himalayan range e.g. *Acer campbellii* (Aceraceae), *Saurauia roxburghii* (Actinidiaceae), *Viburnum erubescens* (Adoxaceae), *Hedera nepalensis* (Araliaceae), *Cynoglossum furcatum* (Boraginaceae), *Prunella vulgaris* (Lamiaceae), *Rubusellipticus* (Rosaceae), *Murraya koenigii* (Rutaceae), and others.

III. *Common elements of the Far-east Asia*: It covers a large area of the Far-east Asia, including some part of Malay Archipelago in the South China Sea, parts of the Philippines and Borneo which includes two important phyto-geographical regions,the continental South-East Asia and the Malaysia region (Takhtajan, 1969, 1986). The elements from the present study are: e.g. *Nephrolepis cordifolia* (Davalliaceae), *Centella asiatica, Ainsliaea latifolia* (Asteraceae), *Castanopsis indica* (Fagaceae), *Arundina graminifolia* (Orchidaceae) and others.

IV. *Mainland Far-East Asian elements*: This plant distribution ranges on the main land of the Far-east Asia with Malay Peninsula as the southernmost limit (Figure 3IV); e.g. *Acer campbellii* (Aceraceae), *Leucostegia immersa,* (Hypodematiaceae), *Viburnum erubescens* (Adoxaceae), *Cynoglossum furcatum, Elaeocarpus lanceifolius,* (Elaeocarpaceae), *Daphniphyllum chartaceum* (Daphniphyllaceae).

V. *Central Himalayan Endemics*: This includes plant elements with very limited natural distribution and found localized in given places of Central Himalaya; e.g. *Galinsoga parviflora, Parthenium hysterophorus* (Asteraceae), *Viburnum cylindricum* (Adoxaceae), *Cannabis sativa* (Cannabaceae), *Prunus nepalensis* (Rosaceae), *Rubia manjith* (Rubiaceae), *P. nepalensis* (Polygonaceae).

4. Estimated Distribution Route Patterns

Based on the distribution range of the plant elements recorded from the study area, the distribution route pattern of the plant elements in the Far-East Asia had been proposed. Consequently, two main distribution trends had been concluded:

A) Southwards route (Figure 4: dotted arrows): This pattern might have their center of origin in the Malesian region. The wide distribution of the plant elements from the Southern region of the Far-East to the North might have occurred mostly by means of "vicariance distribution". The populations of the same taxa in different places of the Far-East Asiatic region could be the relic of population in the past when the land mass of Asia had not separated yet. As the large tree species like *Castanopsis indica* with big fruits and seeds could not disperse over high mountains or through the big oceans, the present distribution range might have represented as the relic of the population which had been separated when the landmass such as Indian landmass, Shan-Thai -Peninsular, Malaysia landmass and others moved forward through the North (Hutchison, 2007). The widely distributed "vicariance" taxon is not only confined to lower montane areas but persists in wide range of altitudes (Hutchison, 2007; Mabberley, 2008). However, for the wide distributed herbaceous taxa bearing small seeds or spores as in orchid species (*Arundina graminifolia*) or ferns (*Nephrolepis cordifolia*, *Leucostegia immersa*) the "dispersal" could be the means of distribution. The dispersal might have been fostered by the presence of small seeds/spores which could scatter freely in the air to transfer to the places away.

B) *Northwards route* (Figure 4: dashed and gray arrows): The plant elements following such route might have taken their center of origin in Himalayan regions. Plant elements following this route might have distributed by means of "dispersal" as they were either endemic to the Central Himalaya or found along the Himalayan ranges. The bases for this understanding could be drawn from the fact that the Himalaya as one of the most recently developed mountains could have allowed those taxa to evolve along with its formation. Accordingly, 'dispersal' might have been used as evolutionary measure by the plant elements for the diversification of taxa along the Himalayan Ranges. The plant elements seeking this kind of distribution trend occurred as common species in one of the present study areas providing generic information of their establishment at same altitudinal range and habitats in other branches of the Himalaya. This route could be further divided into two sub-routes:

B.1) *Westwards route along the West Himalayan branches* (Figure 4: dashed arrows): This includes the areas of westward of Bhutan Himalaya, India (Jammu and Kashmir), Nepal, Pakistan and Afghanistan.

B.2) *Eastwards route along the East Himalayan branches* (Figure 4: gray arrows): This is one of the most interesting distribution routes of plant elements of the world as it connects two large phyto-geographical regions – the Continental South-East Asian region and the Malesian region (Takhtajan, 1969, 1986; Turner et al., 2001). This route branches into two: One continues eastwards through south of China, Myanmar, Thailand, Laos and Taiwan. The other route expands southwards through the range of mountain that connects last range of the Himalaya in the North of Myanmar and Thailand along the range of Mountain between Thailand and Myanmar to Peninsular Malaysia – the Tenasserim range. Presumably, these two routes, besides the Panama channel in Central America, might have been the most crucial routes for the plant elements from the Northern hemisphere to expand to the South. The other route have allowed plant elements to continue through the eastern branches of the Himalaya to the Easternmost ridges via South China and Japanese/South China Sea across Japan till the selected archipelago in eastern China. The diversification of Himalayan element is further enhanced by the prevalence of another sub-branch of the distribution

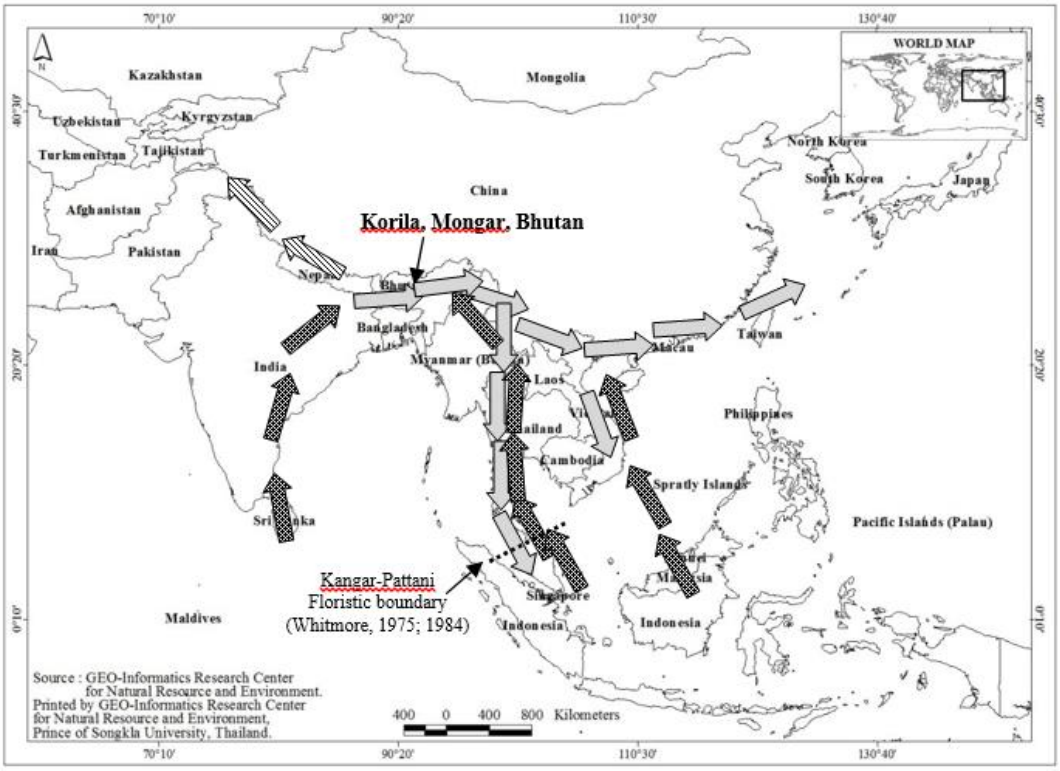

Figure 4. Proposed route and pattern for the distribution of plant elements that occurred in the lower montane of Korila Forest, Mongar, Eastern Bhutan Himalaya with reference to the adjacent regions to Himalaya: dashed arrows - Westwards route, gray arrows - Southwards route, and dotted arrows - Northwards route.

route that continued through the continual ridges of the Himalaya connecting the Annamite range in Vietnam. This route has paramount ecological significance as it is described as one of the most important "cross-roads" of plant distribution ranges of the regions (Voung & Sridith, 2016).

5. Conclusions

The distribution ranges of plant elements in the lower montane areas of Korila, Mongar District, in the Eastern Bhutan Himalaya comprise of five different groups of plant elements: (i) West Himalayan elements, (ii) East Himalayan elements, (iii) Common elements of the Far-East Asia, (iv) Mainland Far-East Asian elements, and (v) Central Himalayan Endemics. The '*true*' Himalayan elements appear to have southernmost limit of their distribution ranges in the North of Thailand, Myanmar, Laos, and Vietnam, places where the Himalayan range ends. Conversely, some elements could extend their southernmost distribution ranges to the North of Malesian Region in the Peninsular Malaysia. Two main probable routes of distribution had suggested that the Himalayan ranges had performed as an important corridor of distribution for many plant elements through its range.

As such, any change in environment by deforestation, forest fragmentation or a reforestation might alter the whole natural distribution chain of the plant elements from Himalaya to the Far-east of Asia. Therefore, all the activities concerning the change of plant species compositions may have to be thought carefully as it might have irreparable impact on the natural population distribution pattern, thus completely interrupting the chain. For all these reasons, there is urgency to conduct plant survey and investigation in the fragile Himalayan areas to gather adequate information of the plant resources. The findings will help to provide guidance for the sustainable consumption or extraction of plant resources besides innumerable benefits to plan the conservation programs.

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