INTRODUCTION

The human life and culture has directly or indirectly been influenced by their surrounding environment. The primitive people were well acquainted with the properties and uses of plants of their surroundings (Jadhav, 2006). They have inherited rich traditional knowledge of surrounding plants used as food, fodder, fibers, woods, fuel, medicine, beverage, tannin, dye, gum, resin, cosmetics, crafts and religious ceremonies (Jadhav, 2006). The listings of plants and animals of ethno biological value are important for knowing and evaluating human-plant relationship to their environment (Alcorn, 1981a, 1984b; Bye, 1979).

Human consumption of wild plants has been documented from antiquity into the common Era. Dietary use of wild fruits, nuts, seeds, and leaves appear in numerous records from ancient Egypt (Darby, 1977), Greece (Athenaeus, 1927-1942), Rome (Apicius, 1958), India (Charaka, 1981), China (Simoons, 1991) and the Medieval era (Arano, 1976). Today, most human plant food is based on rather limited number of crops, but it is clear that in many parts of the world the use of wild plants is not negligible (Prescott and Prescott, 1990; Scherrer *et al.*, 2005; Bussmann *et al.* 2006; Bussman and Sharon, 2006; Kunwar *et al.*, 2006; Cavender, 2006; Pieroni *et al.* 2007). Many publications have emphasized on the diversity and value of wild edible plants (Maikhuri *et al.*, 2000; Kala, 2007; Dhyani *et al.*, 2007). The nutritional value of traditional wild plants is higher than several known common vegetables and fruits (Nordeide *et al.*, 1996;

Sundriyal and Sundriyal, 2001; Orech *et al.*, 2007). The improved and better varieties of fruits, vegetables, cereals and most of other plant products of today are the works of modern scientists by making use of technologies based on the ancient village folk information, on the wild plants (Malla *et.al.*, 1982). Therefore, our ancestors and of course the villagers, are the prime contributors to the development of modern science and technology which has been taking an innovative role in the path of progress and welfare of the society (Malla *et.al.*, 1982).

However, the diversity of uncultivated plant species, their occurrence and relationship with cultivated species and their use by humans has rarely been studied systematically (Grivetti and Ogle, 2000). Changing social values, depopulation of rural areas has led to erosion of traditional knowledge (Maikhuri *et al.*, 2004). Decades of official food security policies worldwide have completely overlooked the importance of most food represented by wild species and harvested from impoverished and agriculturally unproductive lands, herein referred to as marginal lands (Prescott-Allen and Prescott-Allen, 1990). The indigenous people of a particular place generally depend on nearby forest areas to supply their needs. The biological resources are used in many ways, such as timber, fuel-wood, food, wild vegetables, spices, wild fruits, and often important medicines. Among them, WEPs play a major role in supplying food for poor communities in many rural parts of the world (Sundriyal *et*

al., 2003). Wild plants, aside from being used by poor communities, are commonly used today as a supplement for healthy diets in even the most developed regions of the world (Redzic, 2006).

Approximately 75,000 species of plants world-wide are believed to be edible (Walters and Hamilton, 1993). Over the centuries, people have been dependent on this resource for their subsistence as they are efficient and cheap sources of several important micronutrients (Ali and Tsou, 1997). It has even been suggested that wild food plants are nutritionally superior to some of the cultivated ones (Burlingame, 2000). However, these plant resources and their indigenous use are in danger of being lost in areas where environmental and cultural transformations have led to changes in feeding practices. Many indigenous communities abandon or change their traditional customs and thereby lose their plant knowledge over time (Benz *et al.*, 2000; Byg and Balslev, 2001; Ladio and Lozada, 2003). Changes in land-use due to urbanization and habitat destruction, as well as the slash and burn system of traditional farming with its associated shifting cultivation, have been causing forest destruction and degradation.

In developing nations, numerous types of edible wild plants are exploited as sources of food hence provide an adequate level of nutrition to the inhabitants (Aberoumand *et al.*, 2009).Today, most human plant food is based on rather limited number of crops (12 crops contribute more

than 85–90% of worlds caloric intake) (Bussman and Sharon,2006; Kunwar *et al.*, 2006; Cavender, 2006; Pieroni *et al.*, 2007). Wild food plants play a very important role in the livelihoods of rural communities as an integral part of the subsistence strategy of people in many developing countries (Johns and Kokwaro, 1991; Leakey and Newton, 1994). Uncultivated food is an important component of the local society and culture, and loss of those means a loss of important components of culture and religion (Akhtar, 2001).

Besides growing a few crops, people frequently collect wild edible plants for food and other plants from natural habitats to meet their subsistence needs. Use of wild edible plants as a supplementary food resource holds promise. This aspect needs thorough investigation, so that economically important species are promoted for domestication. (Sundriyal *et al.*, 2003). In addition to providing food directly, uncultivated plants provide an opportunity for cash generation (Harris and Mohammed, 2003). Many uncultivated plant resources have significant economic value derived from their collection and sale (Melnyk, 1994). In particular, the hill people depend on a combination of forest products, livestock and agricultural products, and their livelihoods would not be sustainable without these resources (Manandhar, 1995, 2002). The value and potential of uncultivated foods in the food security and nutrition of rural people is also neglected in agricultural and

environmental programs (Gari, 2002; Ogle, 2001; Ogle *et al.* 2003). Also, detailed studies about their availability, status, and contribution in the livelihood support are few (Regmi *et al.*, 2006; Shrestha *et al.*, 2001; Shrestha and Dhillion, 2006).

Vegetables are the edible parts of plant that are consumed wholly or in parts, raw or cooked as part of main dish or salad. A vegetable includes leaves, stems, roots, flowers, seed, fruits, bulbs, tubers and fungi (Uzo, 1989; Uwaegbute, 1989). Vegetables are good sources of oil, carbohydrates, minerals and vitamins depending on the vegetable consumed (Ihekoronye and Ngoddy, 1985). Ononugbu, 2002, reported that vegetable fats and oil lower blood lipids thereby reducing the occurrence of disease associated with damage of coronary artery. Apart from the variety which they add to the menu (Mepha & Eboh, 2007; Subukola *et al.*, 2007), they are valuable sources of nutrients especially in rural areas where they contribute substantially to protein, minerals, vitamins, fibers and other nutrients which are usually in short supply in daily diets (Mohammed and Sharif, 2011). Minerals cannot be synthesized by animals and must be provided from plants or mineral-rich water (Anjorin *et al.*, 2010).

Vegetables are important sources of protective foods, which are highly beneficial for the maintenance of good health and prevention of diseases (Sheela *et al.*, 2004; Nnamani *et al.*, 2007). Indigenous leafy

vegetables are vegetables of a locality which originated from an area and may or may not be confined to that particular region (Guarino, 1997). They account for about 10% of the world higher plants often regarded as weeds. Some indigenous leafy vegetables grow in the wild and are readily available in the field as they do not require any formal cultivation. Many of them are resilient, adaptive, and tolerate adverse climatic conditions more than the exotic species (Raghuvanshi *et al.*, 2001).

Although they can be raised comparatively at lower management cost and on poor marginal soil, they have remained underutilized, due to lack of awareness of their nutritional values in favour of the exotic ones (Chweya and Eyzaguirre, 1999; Odhav *et al.*,2007). Leafy vegetables are rich sources of carotene, ascorbic acid, riboflavin, folic acid and minerals like calcium, iron and phosphorous (Nnamani *et al.*, 2007). George (2003) stated that even though the bulk of their weight is water, leafy vegetables represent a veritable natural pharmacy of minerals, vitamins and phytochemicals. The fiber content of vegetables contribute to the feeling of satisfaction and prevents constipation (Noonan *et al.*, 1999), while the proteins in vegetables are superior to those found in fruits, although inferior to those found in grains and legumes (George, 2003). It is often difficult to determine the nutritional contribution of wild plant foods to total dietary intake because of the lack of compositional data (Faber *et. al.*, 2007). Carbohydrates, fats and proteins are sometime referred to as the

proximate principles and form the major portion of the diet while minerals play an important role in the regulation of metabolic activity in the body (Gopalan *et.,al* 2004).

The importance of antioxidant constituents of plant material has also been established in the maintenance of health by acting against stress related diseases such as, diabetes, cancer and coronary heart diseases (Idowu *et al.,* 2006). Several epidemiological studies suggest that a high intake of foods rich in natural anti-oxidants increases the anti-oxidant capacity of plasma and reduces the risk of some cancers, heart diseases and strokes(Justesen and Knuthsen, 2001). These properties are attributed to a variety of constituents, including vitamins and numerous phyto-chemicals, mainly phenolic compounds such as flavanoids (Justesen and Knuthsen, 2001. Traditional rural diet used to include interesting amount of leafy vegetables (Heinrich *et al.,* 2005). Several greens are claimed to have health- promoting or disease preventing property beyond the basic function of supplying nutrients (Pardo *et al.,* 2005). Vegetables are known as excellent sources of natural antioxidants, and consumption of fresh plants in the diet may therefore contribute to daily antioxidant intake (Chu *et al.,* 2002).

Populations living in Mediterranean countries benefit from a longer life expectancy and a lower incidence rate of chronic diseases than Northern Europeans or North Americans (Simopoulos, 2001; Schröder,

2007). Migrant studies say the Mediterranean diet and lifestyle are behind these societal differences, rather than any genetic or racial factors (James *et al.*, 1989; Darmon and Khlat, 2001; Trichopoulou, 2004). As a matter of fact, traditional Mediterranean diets are unquestionably healthier than North European and American diets: they include a significantly large amount and variety of plant foods (such as fruits, vegetables, wild leafy greens, breads, seeds, nuts and olive oil) and thus guarantee an adequate intake of carotenoids, vitamin C, tocopherols, α-linolenic acid, various important minerals, and several possibly beneficial non-nutrient substances such as polyphenols and anthocyanines (Visioli and Galli, 2001).

As a matter of fact, dietary diversity is a crucial element of a high quality diet (Johns, 2003). Not only does it guarantee an adequate intake of nutrients but also it increases their bioavailability (Kennedy *et al.*, 2003). Recently, a 10-country study conducted by Hoddinott and Yohannes, (2002) using data from Ghana, Malawi, Mali, Kenya, India, the Philippines, Mozambique, Mexico, Bangladesh and Egypt, suggested that dietary diversity could also be a useful indicator of food security (defined as energy availability). Indeed, the results indicated that in each of these ten countries, there was a positive, significant association between household diet diversity and household calorie availability per capita.

However, the dietary intake pattern of people worldwide is changing from a traditional diet (i.e. one containing plant and animal foods harvested from the local environment) to one containing many manufactured, processed, and otherwise non-traditional foods (Kuhnlein and Receveur, 1996). The rapid urbanization might suggest a decrease in the consumption of wild edible plants and a break in the transmission of indigenous knowledge. The risks of the transition from a primarily traditional diet to one containing more market (i.e. store-bought) foods include an increase in the prevalence of chronic diseases and a decrease in the dietary intakes of some key micronutrients that are present (often in abundance) in wild edible plants (Whiting and MacKenzie, 1998).

The people who eat wild edible plants do not usually mention them in nutritional surveys (Kabuye and Ngugi, 2001) but the use of these foods, which has evolved over the decades, has served to provide food and maintain general health among populations. In fact many of the food plants are used for nutrition and medicine (Kabuye and Ngugi, 2001). In Jordan, Tukan *et al.*, (1998) showed different uses of common edible wild plants such as sumac (*Rhus coriara*), chicory (*Cichorium pumilum* Jacq.) and Spanish thistle (*Centaurea iberica* Trev. Ex. Sprengel.), wild lettuce (*Lactuca tuberosa* Jacq.), viper's grass (*Scorzonera papposa* DC.), goat's beard (*Tragopogon coelesyriaca* Boiss.) and gundelia (*Gundelia tournefortii* L.). Interestingly, over half of these plants were consumed raw without any

preliminary preparation other than cleaning and trimming. Many were also consumed as snacks thus providing important sources of nutrients as compared to some modem empty-calorie foods. Tukan *et al.*, (1998) also highlighted the numerous ways of consuming such plants as part of salads, stews, spices or seasoning or even as hot drinks. The actual value of these wild edible plants in the diet of an individual is dependent on a variety of factors, for example frequency of consumption, method of preparation or cooking, freshness and amounts eaten (Shackleton, 2003). When drying leaves, they must not be exposed to the sun since some active compounds or nutrients may evaporate and this then means that they must be green in colour when dry (Bhat and Rubuluza, 2001). Many of the local vegetable materials are under-exploited because of inadequate scientific knowledge of their nutritional potentials (Florence *et al.*, 2011)..

Marketing plays an important role in the socio-economic development of any area as it helps serve the people and the region (Berry, 1967; Sundriyal and Sundriyal, 2004 b). Local economic surveys of the biological resources cannot be completed without studying the plant and animal products sold in the local markets (Bennett, 1992; Wells and Brandon, 1992). A large variety of wild edibles, medicinal and ornamental plants, and various ethno biological utility items are often sold at a much smaller level, probably at the local level only, and very few items flow out of the region in most of the areas (Jana, 1997). Access to market places and

value of their goods, determined by availability, supply and demand (Martin, 1995).

Promoting dark-green leafy vegetables may be difficult, as traditional food crops (e.g. green leafy vegetables) are often seen as the 'poor person's food' (FAO, 1997). Many people are not aware of the nutritional value of such plants and many regard them as inferior (Steyn *et al.,* 2001b). Lack of popularity and unavailability were given as possible reasons for the low consumption of indigenous vegetables (pumpkin leaves 3%; dried green cowpea leaves 3%) observed among college students in Limpopo Province (Mbhenyane *et al.,* 2005). Campaigns promoting these vegetables should focus on the younger generation, as they have less knowledge regarding wild green leafy vegetables Modi *et al.,* 2006). Diet surveys tend to ignore wild plants in comparison to cultivated ones (Etkin *et al.,* 1994), and this is a methodological deficiency (Bonet and Valles, 2002).

Genetic resources of many traditional vegetables are threatened by genetic erosion. This is mainly due to the (i) expansion of mechanized, intensive agriculture (ii) introduction of exotic vegetable species and improved varieties; (iii) loss and degradation of agricultural and forest land (e.g., caused by infrastructure development, soil erosion, and logging of forests to fulfill the demands of the growing population); (iv) over-exploiting of wild plants (e.g., for food, fuel, or fodder); and (v) poor

marketing opportunities for traditional vegetables (Manandhar, 1989). The value and potential of uncultivated foods in the food security and nutrition of rural people is also neglected in agricultural and environmental programs (Gari *et al.*, 2002; Ogle 2001; Ogle *et al.*, 2003). As such, the intake of traditionally consumed wild edible species is nowadays receiving renewed attention, due to the recognition of their potential benefit for human health. (Sa´nchez-Mata *et al.*, 2012). Modi *et al.* (2006) stated that cultivated lands are more suitable for the growth and development of wild leafy vegetables, and the availability of wild leafy vegetables could therefore be enhanced by cultural practices associated with crop management. Liphadzi *et al.* (2006) argued that production of wild leafy vegetables in home gardens or availability thereof in local markets would be advantageous as these vegetables are relatively drought tolerant and grow on soils of limited fertility (Shiundu, 2002). Crop production systems should aim to increase the use of under-exploited natural resources such as traditional food crops (FAO, 1997). As such, the cultivated plants with high chemical inputs such as chemical fertilizers, plant growth regulators, herbicides etc has lost their natural taste, appearance and nutritive values (Sekeroglu *et al.*, 2006). Consumption of cooked and pureed green leafy vegetables was shown to have a beneficial effect on improving vitamin-A status (Takyi, 1999; Haskell *et al.*, 2005). A South African study showed that home-gardens

that focused on dark-green leafy vegetables and yellow/orange fleshed vegetables improved children's vitamin A status (Faber *et al.,* 2002 b). Cooking oil was added during preparation of both *imifino* and spinach for all the children who consumed dark green leafy vegetables during the 5 days recall period. This will have a beneficial effect on improving vitamin A status because fat enhances carotenoid absorption (Jayarajan *et al.,* 1980).

Himalayan regions are particularly rich in biodiversity due to varied geographical, physiographical, topographical, climatic and ecological zones within the region (Khoshoo, 1992). Higher Himalayas are going through the phase of transition due to increasing population pressure, tourism related activities while its rich herbal wealth is in huge market demand (Maikhuri *et al.,* 1998). Besides, harvesting crops after tough hustle in their small and terraced fields and still being paid with low productivity local inhabitants are frequent enough to collect these wild edibles for food and other plants from their natural habitats to meet their subsistence requirements. Use of wild edibles as a supplement in the delicious indigenous hill cuisine is therefore promising (Maikhuri *et al.,* 2001).

In Sikkim Himalaya the natives consume nearly 190 such wild edible species (Sundriyal, 1999). Selection of a particular species for inclusion in the diet is location specific and influenced by the availability

of plant material. Nearly 47 species (fruits and vegetables) come to the market. (Sundriyal and Sundriyal, 2004 b). Among different plant parts, generally higher nutrient concentration was recorded for leaves, followed by new shoots and fruits. (Sundriyal and Sundriyal, 2004 a).

During recent years there has been 'a growing interest to evaluate various wild edible plants for their nutritional value (Arora and Pandey 1996; Bokhary *et al.*, 1987; Bokhary and Parvez, 1993; Dhyani and Khali, 1993; Ifon and Bassir, 1980; Maikhuri, 1991; Maikhuri *et al.*, 1994; Sadhu, 1990; Wesche-Ebeling *et al.*, 1995). Nevertheless, a careful examination of the literature reveals that there are still a large number of wild edible species which are inexpensive and commonly used by locals and whose nutritional potential have not yet been adequately studied (Sundriyal and Sundriyal, 2001). It is suggested that a few wild edible species need to be grown for commercial cultivation and adopted in the traditional agro forestry systems, which will lead to reduced pressure on them in natural forest stands as well as producing economic benefits for poor farmers (Sundriyal *et al.*, 2004). Most of the traditional leafy vegetables have a potential for income generation but fail to compete with exotic vegetables at present due to lack of awareness (Maikhuri, 2000; Jansen *et al.*, 2004). These species are commonly called neglected or underutilized species. Numerous terms have been employed to characterize these less well-known species including minor crops, underutilized species, neglected

species or orphan crops, underexploited, underdeveloped species, abandoned, new, lost, underused, local, traditional, forgotten, alternative, niche and promising species (Padulosi *et al.*, 2003).

Sikkim (Fig. A) is the Himalayan state of India with an area of 7096 sq. km and the altitude ranges from 300 m to 8500 m. The state comprises of four districts: North, East, South and West. In regards to Sikkim the total population is 6, 07,688 lakhs out of which 4, 55, 962 is rural population and 1, 51, 726 population is urban respectively (Census of India, 2011). It is populated by three major ethnic groups of people, the Nepali, the Bhutia and the Lepcha. The food survey shows that 11.7 % of people in Sikkim are vegetarian and 88.3% are non-vegetarians (Tamang, 2007).

The ethnic people of Sikkim consume roots, tubers, rhizomes, leaves and fruits of wild plants. (Rai et al., 2005; Sundriyal and Sundriyal, 2004a). Some of them sell the edible wild fruits, vegetables in nearby markets, which are in high demand among the local consumers.

Taxonomical description, distribution and ethnical importance of wild edible plants have been well documented (Harra, 1966; Bennet, 1987; Sundriyal and Rai, 1996; Rai *et al.*, 1998; Gurung, 2002; Sundriyal and Sundriyal 2004b). Traditional foods have important bearing in the dietary habits of the people of Sikkim (Tamang, 2005). However, information on the nutritional value, socio-economy and anti-oxidant property of the

wild leafy vegetables of Sikkim is meager, except the study conducted by Sundriyal and Sundriyal (2004 a,b), and Rai *et al.*, (2005). The present thesis deals with the studies on some wild leafy vegetables of Sikkim with reference to ecological distribution and nutritional composition.

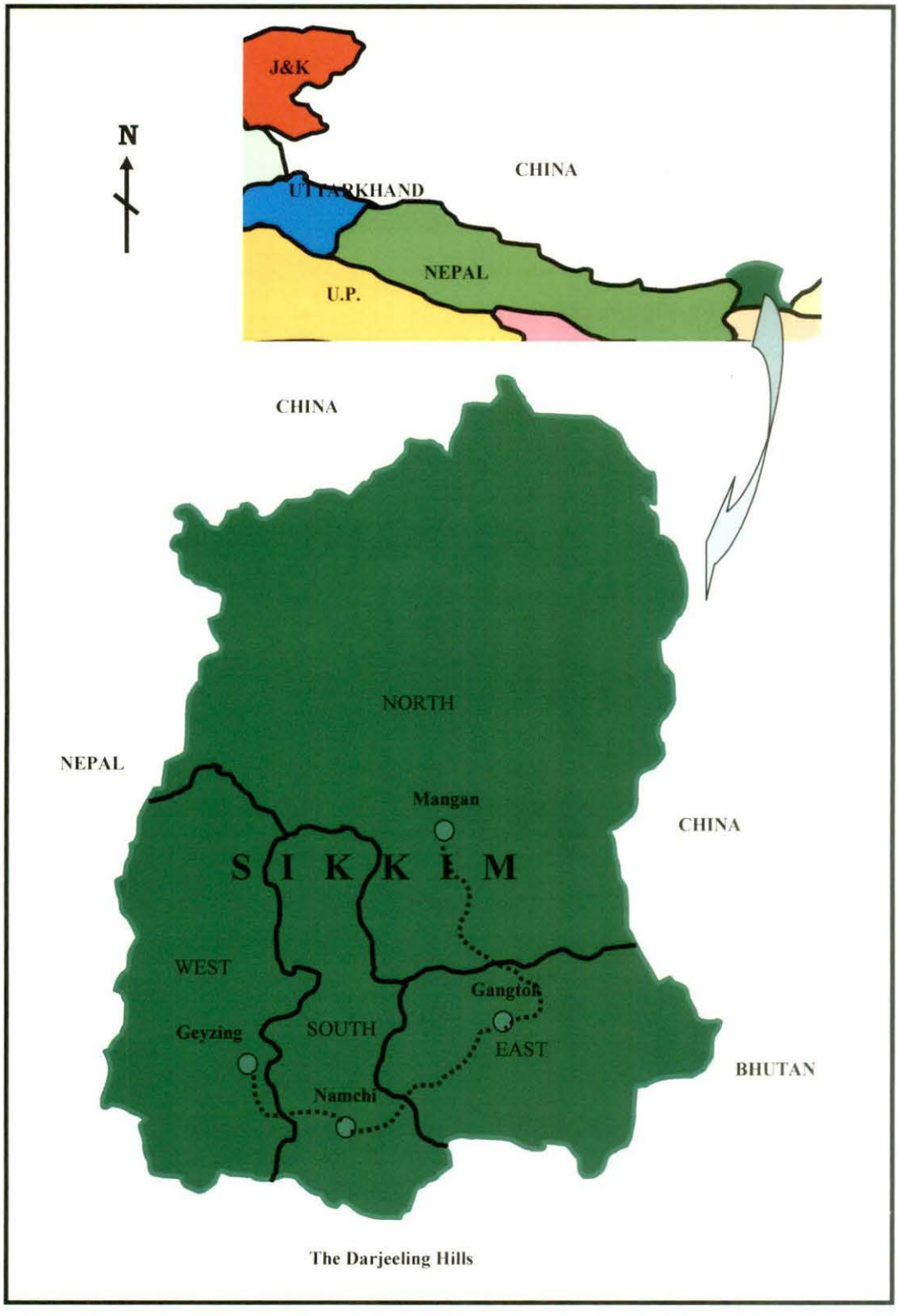

Fig A. Map showing the Sikkim Himalaya

Objectives of the thesis were to:

- To document common and less-familiar wild leafy vegetables consumed by different ethnic people of Sikkim.
- To study ecological distribution and socio-economy of common wild leafy vegetables.
- To determine nutritional composition such as moisture content, ash, protein, fat, carbohydrate, crude fiber, caloric content, vitamin c, beta - carotene, anti-oxidants and minerals.
- To examine microbiological safety of raw wild leafy vegetables.
- To propose a model for domestication of wild leafy vegetables based on nutritive value.